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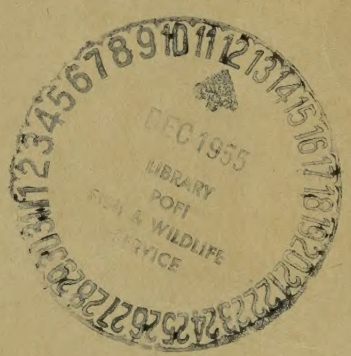

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Records of Oceanographic Works
in Japan Vol. 2, No. 3,
October 1955

Seasonal Variations of the Sea Level Along the Japanese Coasts

By
Masamori Miyazaki
(Kobe Marine Observatory)

1. Characteristics of the seasonal variations

The seasonal variations of the mean sea level are remarkable along the Japanese coasts. The sea level generally rises in summer to autumn, and falls in winter to spring. The mean range of the annual change is from 20 to 40 cm except for the eastern part of the Hokkaido. The semiannual change is also remarkable in many regions, and its maximum range is estimated to be about 10 cm.

The phases and magnitudes of these undulations (Sea and Sea tides) are computed at many stations along the Japanese coasts, which are based on the laborious methods of Darwin (1907) or Doodson (1928). These results are reported by many authorities, and the constants are now given at more than 60 stations all over this area (cf. Ogura 1933, and CMO Tide Tables). Unfortunately, the durations of analysis are generally less than a few years at most of these stations, which are too short to obtain the most reliable values.

Magnitudes of the annual and semiannual variations are not constant, but widely variable from year to year. Fig. 1 shows the variations of the sea-level differences between two methods, September and February, at three stations. Astonishing changes with strong auto-correlations are commonly present in these curves. More obvious evidence will be shown in Fig. 2 where the phases and

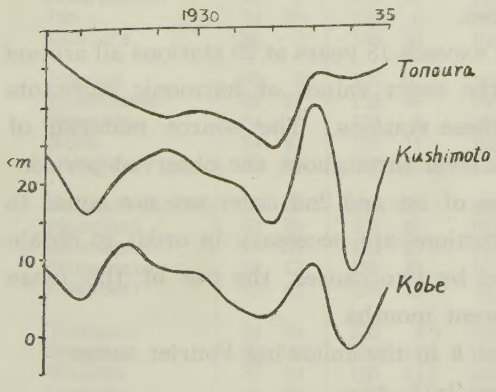

Fig. 1

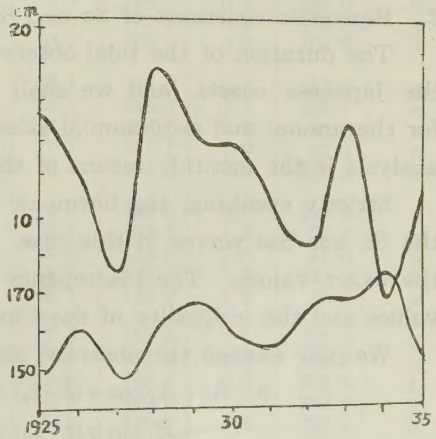

Fig. 2

amplitudes of Sa tide are computed for every year in the period 1925-35 at the Kushimoto harbour. None would conclude these fluctuated values to be the unavoidable anomalies from a constant value. The main origin of these fluctuations will be perhaps the existence of the longer period variations. By this effect, the mean value first tends to the final one when the duration is about 15 years.

In this manuscript, we shall recompute the constants of Sa and Ssa tides by use of the sufficient data, and discuss the regional distributions of them.

Nomitsu's demonstration on the origins of the seasonal sea-level variations (Nomitsu and Okamoto 1925) is surely precious but not the conclusive ones. It is ascertained by them that the statistical effects of the variations in the water density and the atmospheric pressure are of most importance. However, conspicuous anomalies are also found at nearly half of the stations in question. Especially, the computed variations are about twice the actual ones at Ayukawa, situated along the east coast of Honshu. Nomitsu supposed that the density differences were extended to a very deep layer off this station near the polar front, and this was main origin of the anomalies. But the author does not agree with his opinion on this respect.

Strictly speaking, his computed results of the density effects are representatives of the offshore fluctuations, not always the fluctuations at the station, since the mean dynamic depths are computed at a finite pressure for a section off the station. The dynamic effects of ocean currents and the large-scale weather changes will be important for the anomalies as well as the local effects of wind, precipitation, evaporation, and others. Nomitsu already stated that the wind effects were generally small, but the current effects were not so small along the Pacific coast. However, these results will be not the inclusive ones because of small examples and rough estimations. We also fear that the use of the incomplete data would sometimes cause the incomplete results. Excepting his results, we have now very little knowledge on these problems.

2. Harmonic constants of Sa and Ssa tides.

The duration of the tidal observation exceeds 15 years at 25 stations all around the Japanese coasts, and we shall find the exact values of harmonic constants for the annual and semi-annual tides at these stations. The source material of analysis is the monthly means of the sea level throughout the observed period.

Strictly speaking, the harmonic waves of 1st and 2nd order are not equal to the Sa ane Ssa waves in this case. Corrections are necessary in order to obtain the exact values. The discrepancy arises by two causes, the use of the mean values and the inequality of days in different months.

We now expand the observed sea level h in the following Fourier series

$$h = A_0 + A_1 \cos\sigma(t-t_0) + A_2 \cos 2\sigma(t-t_0) + \\ + B_1 \sin\sigma(t-t_0) + B_2 \sin 2\sigma(t-t_0), \qquad (1)$$

where the epoch t_0 is taken at the beginning of a callendar year, and the 1st and

2nd harmonics are the Sa and Ssa constituents. Assuming the mean number of days in a callendar year to be 365.25[1], the monthly mean sea levels will become

$$h_0 = A_0 + 0.95315\ A_1 + 0.26030\ B_1 + \\ + 0.82084\ A_2 + 0.48447\ B_2 \qquad \text{for January,}$$

$$h_1 = A_0 + 0.70670\ A_1 + 0.69386\ B_1 + \\ + 0.01762\ A_2 + 0.96719\ B_2 \qquad \text{for February,}$$

and so on. The integrated means are here adopted. The harmonic constants given by these monthly mean values are of course computed from

$$\left.\begin{aligned} A_1' &= \frac{1}{6}\sum_{n=0}^{11} h_n \cos\frac{n\pi}{6}, & B_1' &= \frac{1}{6}\sum_{n=0}^{11} h_n \sin\frac{n\pi}{6}, \\ A_2' &= \frac{1}{6}\sum_{n=0}^{11} h_n \cos\frac{n\pi}{3}. & B_2' &= \frac{1}{6}\sum_{n=0}^{11} h_n \sin\frac{n\pi}{3}. \end{aligned}\right\} \qquad (2)$$

Then, we easily obtain

$$\left.\begin{aligned} A_1 &= 0.98011\ A_1' - 0.24959\ B_1' - 0.00115\ A_2' - 0.01016\ B_2', \\ B_1 &= 0.24807\ A_1' + 0.98142\ B_1' + 0.00684\ A_2' - 0.01355\ B_2', \\ A_2 &= 0.00365\ A_1' + 0.00460\ B_1' + 0.91959\ A_2' - 0.49603\ B_2', \\ B_2 &= 0.00429\ A_1' + 0.00159\ B_1' + 0.48557\ A_2' + 0.91856\ B_2'. \end{aligned}\right\} \qquad (3)$$

The harmonic constants thus obtained are tabulated in Table 1. In this table, columns H consist of the amplitude, and columns æ of the phase lags.

Table 1—Harmonic constats of Sa and Ssa tides

Station	Locality		Period of Analysis	Sa		Ssa		Reference
	Lat.	Long.		H	æ	H	æ	
	° ′	° ′		cm	°	cm	°	
Hanasaki	43 17	145 35	1925–40	2.6	250.1	2.6	227.8	a
Hachinoe	40 32	145 33	1937–52	10.0	167.4	0.9	11.7	a
Miyako	39 38	141 43	1938–52	8.7	177.6	1.6	253.0	a
Ayukawa	38 18	141 31	1934–52	8.7	183.3	0.7	152.7	a
Chōshi	35 44	140 50	1937–52	12.7	205.1	1.9	219.5	a
Mera	34 55	139 50	1931–52	8.0	182.1	0.7	230.7	a
Yokohama	35 29	139 41	1927–48	9.4	165.6	1.4	196.7	a
Aburatsubo	35 9	139 37	1930–49	8.5	178.7	0.7	235.0	b
Itō	34 58	139 6	1936–52	8.6	173.5	0.3	186.0	a
Uchiura	35 1	138 54	1937–52	10.7	169.9	0.0	104.9	a
Nagoya	35 5	136 51	1914–49	15.1	145.2	0.3	112.2	a
Kushimoto	33 27	135 46	1925–52	13.7	155.8	0.1	358.1	a
Shimotsu	34 7	135 8	1926–52	12.2	150.7	0.8	30.5	a
Kobe	34 41	135 11	1926–52	17.7	151.1	1.9	22.6	a
Uwajima	33 13	132 33	1927–52	12.8	154.4	1.4	332.2	a
Shimizu (Kōchi)	32 47	132 58	1931–52	14.9	154.6	2.7	339.2	a
Hosojima	32 35	131 40	1930–49	13.7	153.2	1.3	37.1	b
Aburatsu	31 35	131 25	1930–52	13.9	154.8	1.6	41.0	a
Minamata	32 13	130 43	1932–50	18.7	148.7	1.7	340.9	a
Fukabori	32 41	129 49	1925–42	18.1	145.9	1.2	23.9	a
Tonoura	34 54	132 4	1925–52	17.3	153.8	1.1	257.2	a
Sakai	35 33	133 14	1932–52	17.6	151.8	2.0	245.5	a
Wajima	37 24	136 54	1930–49	13.6	162.1	2.6	222.8	b
Iwasaki	40 35	139 54	1925–40	8.9	169.8	1.5	290.3	a
Oshoro	43 13	141 1	1930–49	9.5	156.9	1.4	222.4	b

1) The errors are within 0.05 days when the period of analysis is more than 15 years.

These amplitudes are generally smaller than the prior estimatians based on the data of one to a few years. The phase lags are also not in good agreement with the prior results. The phase differences in annual tide are within about 25°, but they often exceed 90° in semi-annual tide.

3. Regional distributions of Sa and Ssa tides along the Japanese coasts.

Phase distribution in Fig. 4 indicates that the Sa tide is maximum in late summer to early autumn except for Hanasaki, in the eastern part of the Hokkaido.

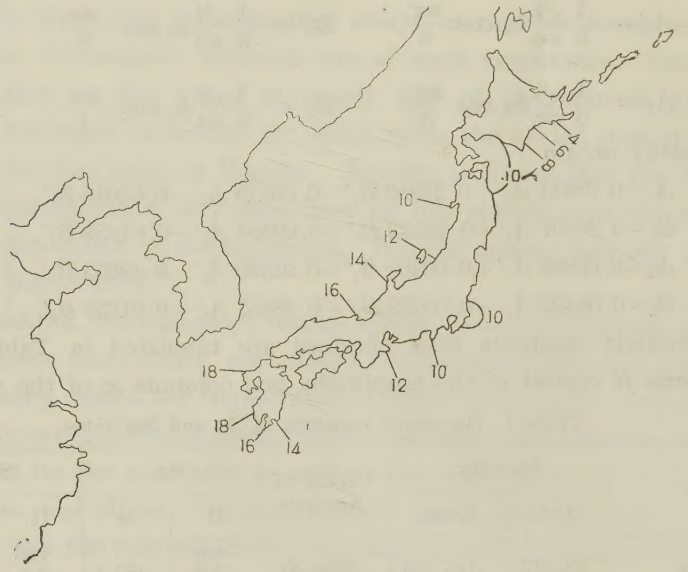

Fig. 3. Amplitudes of Sa tide (cm)

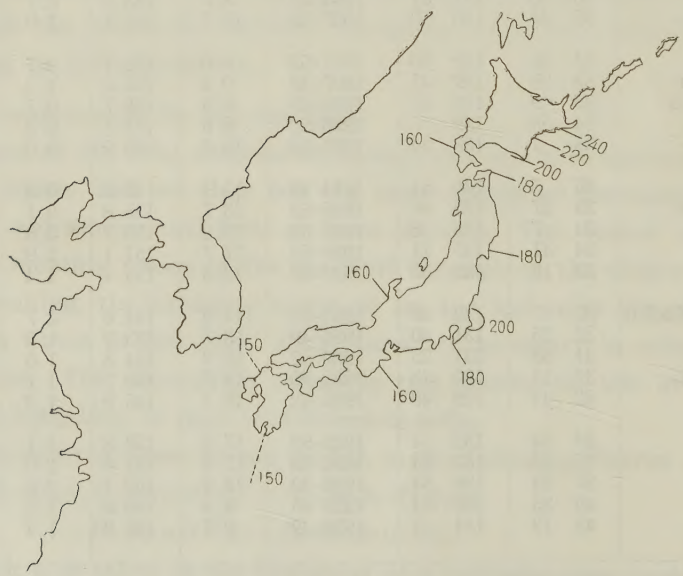

Fig. 4 Phase lags of Sa tide

The corresponding amplitude also falls in a relatively small range 9 to 19 cm excepting Hanasaki. Matters are not so regularly for the Ssa tide of smaller amplitudes, but by no means at random. We shall discuss their regional distributions in the following.

(i) Distributions along the Pacific coast.

In Hokkaidō, the seasonal variations are slight and have two or three maxima. These irregularities will be related with those in the atmospheric pressure variations and relatively small contribbtions of the water density variations. Details are still unknown because of the incomplete data. At Hanasaki, the amplitudes of both tides are nearly equal, and phases are also fairly different from those at southern stations.

The constants seem to be somewhat fluctuated in the eastern Tōhoku district, where the oceanic polar front presents in the offing. According to Nomitsu and Okamoto (1 oc. cit.), the annual variations of the offshore dynamic depth referred to the 200 m surface is nearly twice that of the mean sea level at Ayukawa. The serial oceanographic surveys were made by the Fisheries Experimental Station of the Miyagi Prefecture for the fixed section off the Kinkwazan, and these data in the period 1919–1922 were adopted by them. However, the recent *weather ship* observations along the *C-line* rather indicate far smaller ranges of the dynamic depth variations (cf. Fig. 5). We fear that the older data will be not always approvable. We also have the oceanographic surveys in the neighbouring area made on board the *Tennō Maru* (Fishery Institute) during the period 1920–22. Comparing these two results, we often find the astonishing anomalies of temperature values at the subsurface layers. The *Miyagi FES* values are remarkably higher than the *Tennō Maru* values especially in the summer seasons when the surface air and water temperatures are high and the vertical temperature gradients are large. I suppose that the incomplete use of the Kitahara's bottle would result the mixing or heating of the sample water.

Fig. 5 will successfully explain that the seasonal sea-level fluctuations at Ayukawa are of the same order of those in the offing primarily caused by the variations in the water density. Matters are nearly similar at Hachinoe and Miyako, too. The water density rapidly varies from place to place in this intermediate area, and it will be the main origin of the fluctuations in harmonic constants.

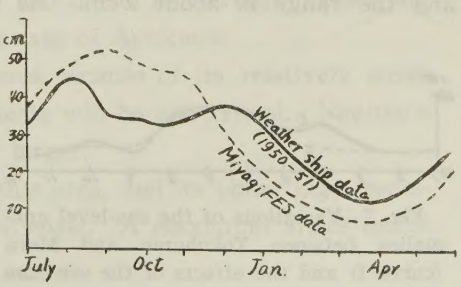

Fig. 5—Variations of the sea level computed from the dynamic depth at 200 db surface.

At Chōshi, in the mouth of the Riv. Tone, the phase of the Sa tide is somewhat later, and the corresponding amplitude is also somewhat larger than those

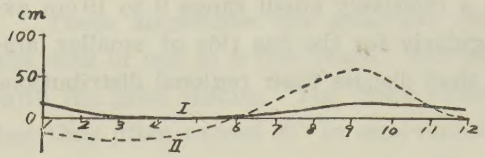

Fig. 6—Water level variations at Choshi (curve I) and in the Kasumigaura (curve II).

at the neighbouring stations. These anomalies are not explained by the variations in the water density, atmospheric pressure, or ocean currents. It will be undoubtful that the discharge from the Riv. Tone is of most importance for these anomalies. In fact, the seasonal water-level variations in her lower stream and in the Kasumigaura (a large lake connected with her lower stream) are somewhat earlier in phase, and far larger in range than those at the Chōshi harbour (cf. Fig. 6).

When we trace the constants from east to west along the southern coast of Japan, the Sa tide generally decrease in phase, and increases in amplitude; the Ssa tide is also likely to show the similar features. The statical effects of variations in the water density and atmospheric pressure are commonly predominant in this area, but the dynamical effects of ocean currents seem to be only important to the west of the Kii Peninsula, which separates the Kuroshio Current from the coast. The offshore sections can be taken outside of the Kuroshio region at the eastern stations. It is clear that the currents are only effective for the sea-level anomalies between the tidal station and the offshore stations across the current region.

The phases in Sa tide are generally earlier at the stations in the recesses of large bays and the Inland Sea than those near their mouths. The corresponding amplitudes are also larger in general. The causes of these anomalies will be the *windstau* and the net supply of land waters.

For instance, the northward winds predominate from September to April, and southward winds from May to August at Yokohama. Applying the Colding's formula, we find that the *windstau* is maximum in July, minimum in January, and the range is about 2 cm. As we plotted in Fig. 7, the sea-level anomalies between Yokohama and Mera are well explained by this effect.

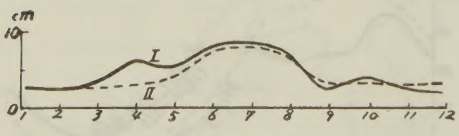

Fig. 7—Variations of the sea-level anomalies between Yokohama and Mera (curve I) and the effects of the *windstau* (curve II).

Another effect, or the net supply of land waters, will be not important except for the Inland Sea area, since the *windstau* well demonstrates the anomalies. However, this effect seems to be fairly important for the Inland Sea area. The sea-level differences between Kobe and Kushimoto are plotted in Fig. 8, which indicates that the range of anomaly is nearly equal to 13 cm. The corresponding *windstau*-curve is also shown in this figure, which is assumed to be proportional to the square of the

pressure differences between Uwajima and Shiono-Misaki. This curve is analogous to that of the sea-level difference, but fairly smaller in amplitude, and somewhat earlier in phase than that.

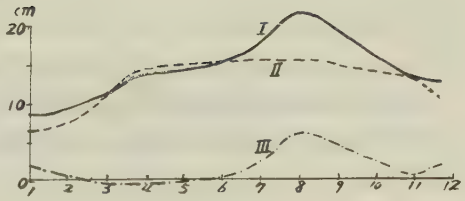

Fig. 8—Variations of the sea-level anomalies between Kobe and Kushimoto (curve I), the effects of *windstau* (curve II), and the residual change (curve III).

The residual change, mainly attributed to the land water effects, is thus predominant in this area, and its range becomes about 8 cm. The net increment of water mass (net inflow of land water minus discharge from mouths without wind effects) becomes negative in autumn to winter and positive in spring to summer, which roughly corresponds to the variations of the net inflow by the precipitation, evaporation, and river discharges.

(ii) Distributions along the East China Sea and the Japan Sea coasts.

The annual sea-level variations along the East China Sea coast fairly resemble to those in the western part of the Pacific coast, but slightly earlier in phase. The amplitudes of Sa tide are 18 to 19 cm, which are the largest values in Japan. Nomitsu and Okamoto well explained the variations at Fukabori by those of the water density and the atmospheric pressure. Unfortunately, we have now very few data in this area to make possible to derive more inclusive results.

Fig. 3 clearly shows that the amplitude of the Sa tide gradually decreases from south to north along the Japan Sea coast. Its origins will be attributed to the corresponding variations in the water density and the atmospheric pressure. In fact, the computed annual ranges of the sea-level caused by the density variations are 31 cm at Tonoura, and 15 cm at Iwasaki; while those caused by the pressure variations are 13 cm at Tonoura, 10 cm at Wajima, and 8 cm at Iwasaki, respectively. The prior computations of the density effects gave too large ranges for Iwasaki (Nomitsu and Okamoto loc. cit.), which will be perhaps caused by the errors of tee observations similarly as the case of Ayukawa.

Current effects will be important in this area because of its relatively small velocities. Excepting Minamata, the wind effects will be also trivial. Nimitsu's estimations on these effects seem to be rather larger.

Ssa tide is relatively regular throughout this area, and its phase lags resemble to those in the northern part of the Pacific coast. A maximum arises in the middle of January to the middle of February.

4. Origins of the seasonal sea-level variations.

Summarizing these results, we may conclude that the seasonal sea-level variations along the Japanese coasts generally belong to the "oceanic type" which is primarily caused by those in the water density and the atmospheric pressure.

However, it is also the fact that we often have the severe effects of winds and land waters in shallow long bays and near the river mouths. Especially, these effects are predominant in the Inland Sea.

Remarkable anomalies between theory and observation were ever shown at Ayukawa and Iwasaki (Nomitsu and Okamoto loc. cit.), which are now corrected by taking more accurate observations into account.

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A Method to determine the Time of Ring-Formation in Hard Tissues of Fishes, especially for the Age Determination of Pacific Tunas

By
Yukio Nose, Sayako Tomomatsu, Koya Mimura and Yoshio Hiyama

(Fisheries Institute, Faculty of Agriculture, Tokyo University)

1. Introduction.

In any case of age determination of fishes by hard tissues, such as scale, bone, fin ray and others, the ring or mark we are reading should be proved to be made once for each year. There are some methods to prove it, for example, rearing the fish in the aquarium and to know the environmental and physiological condition necessary to make such a sort of mark in the hard tissue.

On the other hand, the microscopical observation of hard tissues collected periodically and continuously throughout a year will tell us the seasonal change of position of the ring in hard tissue according to its growth in a certain direction.

Of this method, an index to see when the ring would be made is the percentage of the individual of fish, which has the ring at the margin of the hard tissue in total samples, if this hard tissue is always newly made at their margin. And when the index is maximum during a year, it tells most of the fish of this species make the ring in that hard tissue at this season of a year.

This has been used for smelt, *Hypomesus olidus* by Amemiya and Hiyama (1940), for mackerel, *Pneumatophorus diego* by Fitch (1951), for O-aged sardine by Tamura (1952), for croaker, *Nibea imbricata* by Saishu (1955), for white croaker, *Nibea argentata* by Saishu and Nakajima (1955), and for yellow croaker, *Pseudosciaena manchurica* by Ikeda (1955).

However, this method has difficulty to identify whether the ring is right at the margin or somewhat inner from it, especially in the case that the ring is a fine line such as that of herring scale and the similar type.

So, here when we work out about the scale reading of tunas, we have to use the another method to ascertain in what season the ring (see Fig. 1) is made.

It is based on the seasonal change of the marginal increment widths measured as the distance from the last ring to the margin of scale. As it is very difficult to get a same size of scale from various fish individuals, the proportion of the marginal increment widths to the length of scale, viz., $\frac{T-R}{T}$, where T is the

length of scale measured from focus to the margin and R is the distance from focus to the last ring, is measured as the index about the number of fishes in each month. And when the index is minimum, it could be regarded as the time of ring-formation.

This method has been used mainly for sardine by Yasuda (1940), Walford and Mosher (1943), Kubo (1950), Sato and others (1950), Tamura (1952) and for black croaker, *Nibea nibe* by Kibesaki and Masago (1955).

However, this phenomena can be seen clearly either when we measured that of a single individual of fish or the numerous individuals make the ring exactly simultaneously, and the index in minimum point would be near to zero in these cases.

But, as usual, in most of livings such a physiological period as to make a ring in hard tissue has individual variation regarding with time. In other word, in a certain time of a year, some of individuals already made a new ring, but others are not. In this case, though it is just a season of ring-formation, the index, $\frac{T-R}{T}$, of the former is minimum and near to *O*, but the index of the latter is just the maximum throughout a year, because the minimum of the index occurs just after the time of the maximum.

So, if we take the average figure of the index for all the numerous individuals of fish sampled in respective season of a year, we have to check when the most of fish individuals make the ring in fish, by seeing the seasonal change of the average index for all the samples, especially in the case that the minimum value of the index is not near to *O*.

For this purpose, we have to utilize the Fourier's analysis to analyse the wave of the index to know about the extent of variation of the time of ring-formation among the individual fish sampled, and the proportion of the number of individuals which form a ring to all the sampled fish at a certain season of a year.

This report is just to introduce this method of analysis and to inform these data we could obtain about three species of tunas, i. e. albacore, *Germo germo*, yellowfin tuna, *Neothunnus macropterus*, and big-eyed tuna, *Parathunnus sibi*.

The scale samples were collected by the co-operation of the Nankai Fisheries Research Station, headed by Dr. Hiroshi Nakamura, and measured by Tomomatsu and partly by Mimura and the index were obtained by these. The Fourier's analysis was made by Nose about these data by the mathematical help of Mr. Kinjiro Kajiura, Geophysical Institute, Faculty of Science, Tokyo University. The plan of this research was established by Hiyama and he oversaw the work throughout.

The authors wish to express their thanks to the stuff of Nankai Fisheries Research Station, Dr. Nakamura, Yabe and others and also to Mr. Kajiura at this occasion.

And here we have to mention that the expense of this research are partly

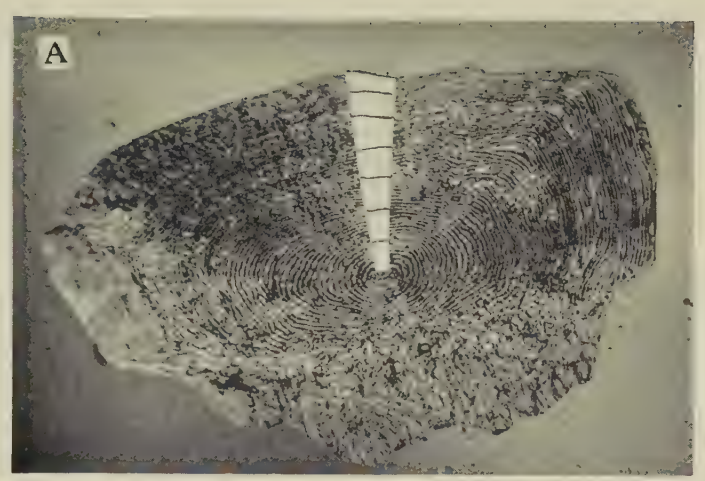
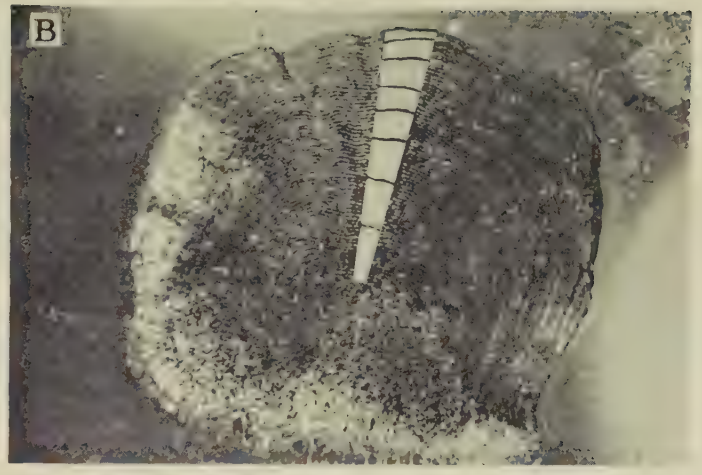


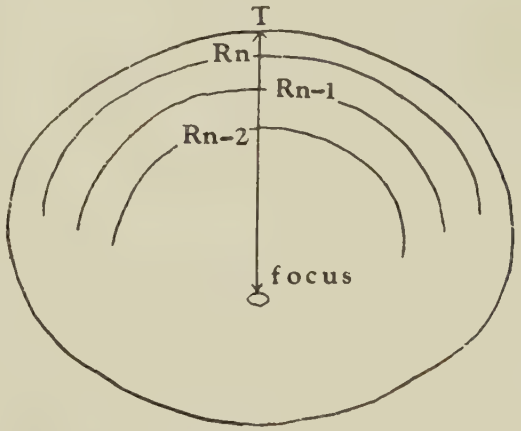
Fig. 1 (A) An albacore scale with six year rings.
Fork length of fish 81 cm. ; Caught March, 1953. (×16)



(B) A yellowfin tuna scale with seven year rings.
Fork length of fish 110 cm. Caught April, 1952. (×16)

(C) A big-eyed tuna scale with eight year rings.
Fork length of fish 129 cm. ; Caught May, 1952. (×16)

D



(D) The illstration showing the direction measured.

aided by Department of Agriculture and Forestry of the Government.

2. Materials.

The materials were collected continuously at the Tokyo Fish Market once or twice a month. The fishes from which the materials were taken, were caught by long-line commercially in various area of the Pacific. Albacore was collected from February, 1953 to January, 1954, yellowfin tuna from April, 1952 to February, 1953 and big-eyed tuna from March, 1952 to January, 1953. The length of fishes were measured as centimeter, from tip of snout to the center of fork of caudal fin. On the other hand, we obtained the data as to the fishing date, fishing locality and fishing conditions at the time when the fishes were caught, from the skipper of each tuna fishing boat.

The scales were taken from an area under the IV–VIth finlet of caudal peduncle, for the scales from this region were so thin that suitable for reading.[1)]

About ten or more scales collected from one individual were set between two slide glass of which both ends were bounded by label paper after the dirt was removed.

All these species of tunas have cycloid type of scale having neither teeth nor radii. The circulii are clear and concentric with the margin at the covered portion of scale.

We regarded the following ring as a year ring. The ring appears as a transparent line, near by which the circulii become fine and discontinuous as shown in Fig. 1.

Then, T, the distance from focus to the margin, R_n, from focus to the last (outer most) and the n_{th} ring, and

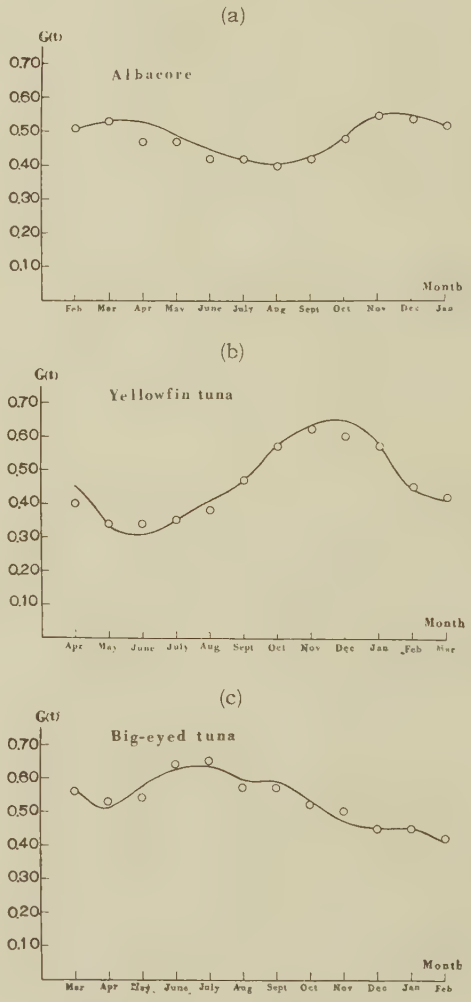


Fig. 2. The wave of average index, $T-R_n/\frac{R_n-R_{n-2}}{2}$. (a) albacore, (b) yellowfin tuna and (c) big-eyed tuna.

1) Westman and Gilbert (1941) reported that the scales from an area under the second dorsal fin were suitable for reading in young Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus).

TABLE 1. G, the average index for marginal increment widths, N, the number of fishes examined and S.D., the standard deviation in each month.

(a) albacore (1953–1954)

	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
N	14	20	28	22	9	14	22	7	17	20	13	25
G	0.51	0.53	0.47	0.47	0.42	0.42	0.40	0.42	0.48	0.55	0.54	0.52
S.E.	0.03	0.03	0.08	0.03	0.04	0.03	0.02	0.04	0.03	0.03	0.02	0.02

(b) yellowfin tuna (1952–1953)

	Apr.	May	June	July	Aug.	Sept.	Oct.*	Nov.	Dec.*	Jan.	Feb.	Mar.*
N	25	50	10	40	45	7		23		18	18	
G	0.40	0.34	0.34	0.35	0.38	0.47	0.57	0.62	0.60	0.57	0.45	0.42
S.D.	0.10	0.05	0.03	0.06	0.06	0.10		0.04		0.04	0.03	

(c) big-eyed tuna (1952–1953)

	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.*	Jan.	Feb.*
N	5	24	65	35	46	43	28	20	33		18	
G	0.56	0.53	0.54	0.64	0.65	0.57	0.57	0.52	0.50	0.45	0.45	0.42
S.D.	0.07	0.12	0.13	0.92	0.42	0.07	0.10	0.05	0.06		0.04	

Note—the data with * mark were estimated from front and rear data.

R_{n-2}, from focus to n-2_{th} ring were measured by the image of scale enlarged by projector.

We got the index of marginal increment for convenience as following. G'(the index) $= T - R_n / \frac{R_n - R_{n-2}}{2}$. G' in each individual and the average index, G, was acquired for each month.

The number of fishes examined, G, the average index and standard deviation were tabulated in Table 1 and G shown in Fig. 2.

3. Method to Analyse.

As the first step, theoretically G', the index in each individual is thought to be a rectangular triangle wave just like *teeth of saw* having a period as one year, of which minimum is O and the maximum is 1 as indicated in Fig. 3. In this case, the maximum point (=the minimum point) can be regarded as the time of ring-formation.

However, G, the average index for numerous individuals we acquired is resemblant to a sine curve in shape as already shown Fig. 2. Such a phenomena can be caused by the individual variation of the phase of above mentioned triangular waves.

Now, if at a certain month the number of individuals which have a certain height of the triangular wave, h_1 is a_1, having h_2 is a_2, and having h_3 is a_3, so

and so, the average index for these individual of this month is as follows,

$$G=\frac{h_1a_1+h_2a_2+h_3a_3+\cdots\cdots}{N}=$$

$$=h_1\frac{a_1}{N}+h_2\frac{a_2}{N}+h_3\frac{a_3}{N}+\cdots(1)$$

where $N=a_1+a_2+a_3+\cdots\cdots$ which is the total number of fishes for that month and $\frac{a_1}{N}$, $\frac{a_2}{N}$ and $\frac{a_3}{N}\cdots\cdots$ are thought to be the probability of respective wave height.

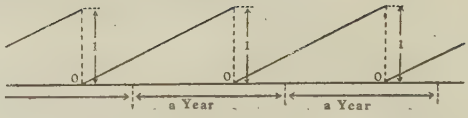


Fig. 3 The illustration showning the growth of marginal increment widths in a single individual of fish.

So, by putting $\frac{a_1}{N}=p_1$, $\frac{a_2}{N}=p_2$ and $\frac{a_3}{N}=p_3,\cdots\cdots$

we obtained

$$G=p_1h_1+p_2h_2+p_3h_3+\cdots\cdots \qquad (2)$$

where $p_1+p_2+p_3+\cdots\cdots=1$

If we express the above mentioned triangular wave as $H(t)$ and the probability density function as $f(\tau)$, then (2) can be represented as follows

$$G(t)=\int_{-\pi}^{\pi}f(\tau)\ H(t+\tau)\,d\tau,\ \text{where } t=\frac{2\pi}{12}\ T \text{ of which unit is month.}$$

And $f(\tau)$ is so valid between the limits $\tau=-\pi$ and $\tau=\pi$ that

$$\int_{-\pi}^{\pi}f(\tau)\,d\tau=1 \qquad (4)$$

Now, assuming the origin of time at the center of teeth of triangular wave (O in Fig. 4), we get

$$H(t)=\frac{1}{2}+\frac{1}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{n}\sin nt \qquad (5)$$

And substituting (5) in (3) considerating (4), we obtain,

$$G(t)=\int_{-\pi}^{\pi}f(\tau)\left\{\frac{1}{2}+\frac{1}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{n}\sin n(t+\tau)\right\}d\tau$$

$$=\frac{1}{2}+\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{n\pi}\left(\sin nt\int_{-\pi}^{\pi}f(\tau)\cos n\tau\cdot d\tau+\cos nt\int_{-\pi}^{\pi}f(\tau)\sin n\tau\cdot d\tau\right) \qquad (6)$$

Meanwhile, developing $G(t)$ in Fourier's series,

$$G(t)=a_0+\sum_{n=1}^{\infty}(b_n\sin nt+a_n\cos nt) \qquad (7)$$

where $a_0=\frac{1}{2\pi}\int_{-\pi}^{\pi}G(t)\cdot dt$, $b_n=\frac{1}{\pi}\int_{-\pi}^{\pi}G(t)\sin nt\cdot dt$ and $a_n=\frac{1}{\pi}\int_{-\pi}^{\pi}G(t)\cos nt\cdot dt$.

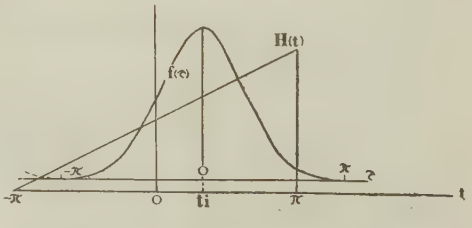


Fig. 4 The illustration showing $H(t+\tau)$, the triangular wave height and its probability density function, $f(\tau)$.

As the values for the coefficients of the sine terms and cosine terms in (6) and (7) are to be equivalent to each other,

$$\left.\begin{aligned} &\int_{-\pi}^{\pi} G(t)\,dt = \pi, \\ &f(\tau)\cos n\tau \cdot d\tau = (-1)^{n-1} n \cdot b_n \\ &f(\tau)\sin n\tau \cdot d\tau = (-1)^{n-1} n \cdot a_n \end{aligned}\right\} \qquad (8)$$

Developing $f(\tau)$ in Fourier's series, it happened to obtain the value for the coefficients of sine and cosine terms in (8) eventually. So we could get

$$f(\tau) = \frac{1}{2\pi} + \sum_{n=1}^{\infty} (-1)^{n-1} \cdot n \cdot (a_n \sin n\tau + b_n \cos n\tau) \qquad (9)$$

Thus, we could obtain the value for the coefficients of sine and cosine terms of $f(\tau)$ easily, by developing the wave of average index in Fourier's series.

4. Results

(i) The probability density function, $f(\tau)$.

As the first step, according to the method of Fourier's analysis described by Tsuboi (1943), we developed the data in Table 1 in Fourier's series for each species as follows,

albacore ; $G(t) = 0.49 + 0.06\cos t - 0.02\cos 2t - 0.01\cos 3t + 0.01\sin t - 0.02\sin 2t - 0.01\sin 3t,$

yellowfin tuna ; $G(t) = 0.46 + 0.03\cos t - 0.02\cos 2t - 0.14\sin t + 0.03\sin 2t + 0.04\sin 3t + 0.02\sin 4t + 0.01\sin 5t.$

and

big-eyed tuna ; $G(t) = 0.53 - 0.08\cos t - 0.02\cos 4t - 0.01\cos 5t - 0.01\cos 6t + 0.05\sin t + 0.01\sin 4t.$

Each $G(t)$ above acquired was represented in Fig. 2 by a line.

As the second step, according to (9) in foregoing section, we could get $f(\tau)$, the probability density function as follows,

albacore ; $f(\tau) = \frac{1}{2\pi} + 0.06\sin\tau + 0.04\sin 2\tau - 0.03\sin 3\tau + 0.01\cos\tau - 0.04\cos 2\tau - 0.03\cos 3\tau,$

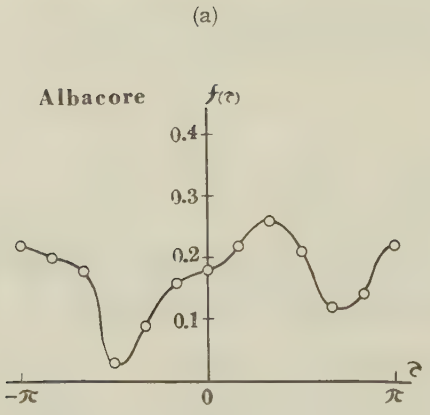
yellowfin tuna ; $f(\tau) = \frac{1}{2\pi} - 0.03\sin\tau + 0.04\sin 2\tau - 0.14\cos\tau - 0.06\cos 2\tau + 0.12\cos 3\tau - 0.08\cos 4\tau + 0.05\cos 5\tau.$

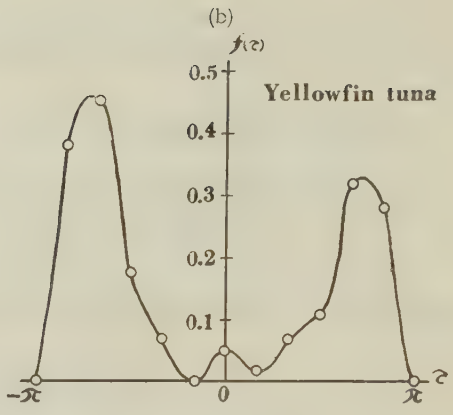
and

big-eyed tuna ; $f(\tau) = \frac{1}{2\pi} - 0.08\sin\tau + 0.08\sin 4\tau - 0.05\sin 5\tau + 0.05\cos\tau - 0.04\cos 4\tau.$

and $f(\tau)$ in each fish species was shown in Fig. 5 respectively.

As shown in Fig. 5, each $f(\tau)$ had two or more modes contrary to our expectation that the $f(\tau)$ would be resemblant to the normal distribution curve.





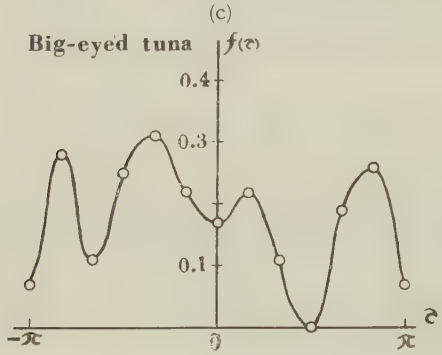


Fig. 5 The probability density function, $f(\tau)$ acquired by calculation. (a) albacore (b) yellowfin tuna and (c) big-eyed tuna.

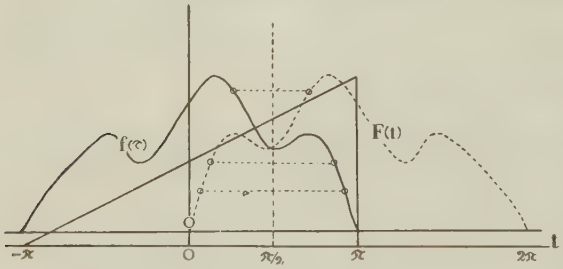


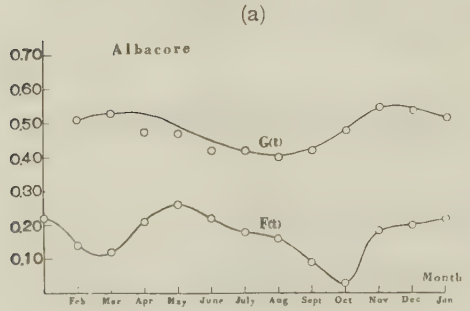
Fig. 6 The illustration showing the $F(t)$ is represented as symmetrical as $f(\tau)$ taken in $t=\frac{\pi}{2}$ as the axis of symmetry.

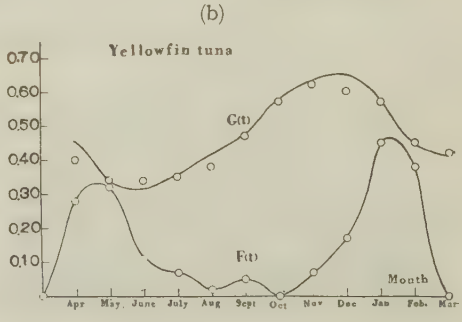
(ii) The proportion of the number of individuals which form a ring at a certain month of a year.

The monthly proportion of the number of individuals which form a ring, $F(t)$, can be obtained from $f(\tau)$ by Fig. 6. Because, when $t=0$, the proportion of the number of individuals having the maximum height of $H(t)$, is $f(\pi)$ and when $t=t_i$, the proportion is $f(\pi-t_i)$.

So, $F(t)$ may be represented as symmetrical as $f(\tau)$ taken in $t=\frac{1}{2}\pi$ as the axis of symmetry.

So, we could obtain $F(t)$ as shown in Fig. 7 in comparison with the wave of index, for these species respectively.





(c)

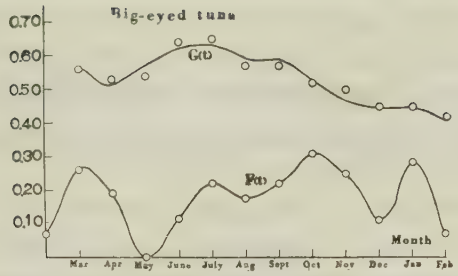


Fig. 7 The relation between the position of $F(t)$ and the wave of average index. (a) albacore (b) yellowfin tuna and (c) big-eyed tuna.

5. Consideration

As metioned in the introduction, the previous workers are merely checking $G(t)$ and thought the minimum of this index is the time of the ring formation. However, here as shown in Fig. 7 for each respective species, if $F(t)$ is compared with $G(t)$, it is appearent that the maximum of $F(t)$, which means the most numerous individuals make the ring at that time, does not correspond with the minimum of $G(t)$, in all three species of tunas. This evidence tells us that without finding $F(t)$ by this sort of analysis we can not decide the time of ring-formation in hard tissues of fish.

Fig. 7 shows apparently more than one peak in $F(t)$ about all species of tunas, though we were expecting one maximum for $F(t)$ to be the time of ring formation. Albacore has the one in early Summer and the another in Winter. Yellowfin has the one in Spring and the another in winter. Big-eyed tuna has somewhat four peaks. This can be comprehended as follows.

At the begining of this analysis, we had assumption that all the individuals of tunas form a ring once at a certain time of a year. So, if this assumption is true, this phenomena tells the possibility that some groups of tuna having different season of ring-formation exist in the Pacific Ocean. If we could get more samples enough to separate the group according to the fishing locality or other factor to get more simple and typical $f(\tau)$ curve, we would be able to discuss further. However, the data of this work is not enough to do so, and this possibility can be proved from another direction, such as morphometry and others later.

On the other hand, it is possible that the assumption here we used might not be true. However, if almost of all these individuals make the ring in scale more than once in a year, the peak values of $F(t)$ should be much higher than the values in Fig. 7 we actually obtained and would be near to 1. We hoped to change the assumption in next step that the ring was formed twice a year to see more typical $f(\tau)$ might be found, but no method to analyse by Fourier's series is found, because the sampling was made monthly and only six units is for one period, so we can not go further.

Morever, if the rings of scales of these fishes were made more than once in a year, the growth rate obtained by this sort of age determination should be different from that obtained from other method by twice or thrice. However, as we may publish it later, the growth rate we are getting by this scale reading method is not so different from that ascertained by vertebral reading and by length frequency distribution done by previous workers.

Therefore, at present paper to introduce a method to check the time of ring formation in scale or other hard tissues of similar growth, we merely want to mention that there is some possibility that these tunas in the Pacific may have some group having different time of ring formation in scales each other.

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Comparative Studies on the Red Tide Appeared in the Waters Adjacent to Western Japan

By
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(Seikai Regional Fisheries Research Laboratory)

1. The explosive multiplication of plankton and the red tide.

Explosive growth of the plankton population has been said to be the red tide or the red water, and these names represent the nature of those appearances. In Japan there have been reported on the discolouration of sea water by plankton which are called as to white water, green water, red water and pink water. In the other countries, there are many kinds of the expression in manifesting the actual conditions of appearance of such explosive multiplications of plankton as the red water. Many such names of explosive multiplications as rapid growth, outburst, outbreak, phytoplankton blooming, phytoplankton flowering, and diatom blooming have been called respectively, and these names have represented rapid growth pattern of plankton population. For representing the state of discolouration of water it is usually said that red water or red tide has appeared.

At any rate, already in the year of 1820, William Scoresby discribed on his report "Whaling Expedition in European North Polar Sea", that long bands of discoloured water and streams of discoloured water recognized to be caused by diatom were observed. Charles Darwid (1839) discovered the red tide of *Trichodesmium* sp. in the waters off Chile during his cruise in 1832, while his circumnavigation. One may call his description on the red tide of *Trichodesmium* the first scientific report on the red tide. After Darwin the red tide and the discolouration of sea water by plankton have been one of interesting objects of scientific researches among marine biologists. Darwin's observation on this discoloutation of water expressed that bands or lanes of discoloured water were pale reddish tint in colour. This is obviously the discolouration of water by plankton and this sort of discolouration has been known to be caused by the sporadic proliferation of the given microplankton.

The author has been studying on the red tide in the waters off western Japan, with special reference to physiological-ecological point of view. In order to advance the study of the red tide, the author has introduced a system of growth composed of three main parts: (i) living cells endowed with biotic potential (capability of reproduction), in the form of either uni-or multicellular organisms, (ii) a suitable source of energy, and (iii) an environment which permits growth,

Table 1. Appearance of the red tide in the water off western Japan in recent years.

Species of plankton	Water colour	Time of discolouration
Noctiluca scintillans	pale red	April, 1947. April and May, 1948. February and June, 1949.
Dictyocha fibula	red	August, 1947.
Rhizosolenia styliformis	white	January, 1949.
Trichodesmium sp.	white	September, 1949. August, 1953.
Rhizosolenia styliformis var. *latissima*	pink	May-June, 1955.

into a conceptian of the plankton blooming. Red tides examined by the author can be shown in Table 1.

2. Red tide of *Dictyocha fibyla* **Ehr.**

In the cases of the red tide mentioned above, *Dictyocha fibula* caused discolouration of the water in Omura Bay immediately after a small quantity of

Table 2. Weather conditions before onset of the red water of *Dictyocha fibula* and during the period of the red water August 1947, in the Bay Omura in western Kyushu, Japan.

Date	Air temp. °C	Vapor tension	Hrs. of sunshine by Jordin	Precipitation (mm)	Cloudiness
1	26.7	20.5	7.11	3.3(2)	8.0
2	27.0	20.0	11.30	—(—)	7.3
3	27.1	20.8	9.50	1.1(1)	6.3
4	27.1	21.0	11.13	0.4(1)	3.3
5	27.0	20.9	8.78	0.7(1)	9.7
6	27.1	21.3	7.46	—(—)	8.0
7	26.4	21.4	5.30	8.5(2)	7.7
8	25.3	22.1	3.00	28.2(8)	10.0 *
9	27.3	22.5	10.05	0.0(—)	7.7
10	27.2	22.9	11.08	1.2(2)	5.7
11	26.2	20.4	12.30	—(—)	0.3
12	26.6	20.1	12.45	—(—)	4.7
13	26.9	20.4	12.25	—(—)	1.3
14	27.9	20.5	12.45	—(—)	4.0
15	27.5	20.2	12.35	—(—)	0.7
16	27.0	20.5	11.30	1.4(—)	2.7
17	26.5	20.4	9.22	—(—)	5.7
18	26.2	20.7	7.70	0.7(2)	9.3
19	26.8	20.0	10.75	—(—)	4.0
20	26.3	18.9	11.88	—(—)	0.3
21	26.4	19.1	12.00	—(—)	0.0
22	26.3	17.7	12.30	—(—)	0.3
23	27.9	20.3	11.85	—(—)	2.7
24	24.1	20.8	3.75	14.7(3)	5.7
25	24.9	20.5	4.43	27.7(7)	10.0
26	26.2	20.3	10.91	0.0(—)	5.7
27	26.4	21.2	10.45	0.1(—)	2.7
28	27.4	21.0	2.91	—(—)	10.0
29	27.2	19.4	6.00	—(—)	7.7
30	27.7	22.1	11.60	—(—)	1.0
31	27.2	21.7	11.55	—(—)	6.0

* ..... Onset of red water.

precipitation (about 37 mm on August 7, 8, 1947, as shown in Table 2) during a long spell of fine weather in the summer. And the red tide outbroke in the central part of an anticlockwise circulation in the northern half of the bay. It is considerable that the *Dictyocha* red tide occurred under such physical conditions that the discrete water mass had developed due to lowered viscosity of water by serve sunshine and a little precipitation in the meantime. The lowering of the viscosity is important in such a physiological aspect as rising in absorption rate of the nutrients in the cell of the red tide plankton takes place.

Although physical and chemical conditions of the environment are satisfied, it may be considerable that the biological reason why the plankton community transforms into the monospecific popluation in its population structure as shown in Table 3, is the most important for studying of the cause of the red tide. Owing to the author's observation of the red tide, it seems that change in population structure is caused by a sort of auttoxines. From biochemical point of view, the

Table 3. Community relationship of Plankton between a water sample before discolouration and a sample of red water caused by *Dictyocha fibula* in Aug., 1947.

Pl. community in water before discolouration (Aug. 2nd, 1947)		Pl. community in discoloured water	
Chaetoceros Schuttii	CC		
Ch. decipiens	+		
Ch. didymus	+		
Ch. spp.	CC		
Rhizosolenia stolterfothii	+		
Rh. spp.	+		
Thalassiothrix flauenfeldii	C		
Bacteriastrum varians	C		
Nitzchia seriata	+		
Coscinodiscus janishi	+	*Dictyocha fibula*	CC
Asterionella japonica	+	*Gymnodinium simplex*	C
Pleurosigma affine	+	*Candacia pachydactyla*	R
Ceratium fusus	+	*Chaetoceros decipiens*	RR
Dictyocha fibula	RR		
Calanus tenuicorinis	+		
Oncaea media	C		
Candacia pachydactyla	C		
Copepods nauplius	C		
Oikopleura sp.	+		
Sagitta sp.	R		
Fritillaria sp.	R		
Echinopleuteus larva	+		
Zoea larva	R		

onset of rapid growth of a species of plankton is due to such a mechanism as growth promoting substance takes an active part in metabolism for high rate of population growth of plankton at the same time with its ontogenic adaptation, and transformation in population structure from community to monospecific population is to inhibitory substances or toxines for other organisms.

3. White water of *Trichodesmium* sp.

White discolouration of sea water by *Trichodesmium* sp. was observed in the waters adjacent to the Danjo Is. off western Kyushu of Japan both in September, 1949 and August, 1953. Each discoloured water covered the same sea area of about a half of the eddy, and this discoloured water mass was discreted in this eddy. It is recognized by the vertical distribution of chemical properties observed in both years of 1949 and 1953 that this discoloured water mass in the eddy was discreted by the boundary at a depth of 50–75 meters as shown in Table 4.

Table 4. Results of observation of white water mass discoloured by *Trichodesmium* sp. in the waters around the Danjo Is. off western Japan ; September, 1949.

Observed layer m.	Tw °C	Cl ‰	O_2 cc/l	SiO_2 mg/m³	P_2O_5 mg/m³
St. 5 : 32°12, O′N 129°03, O′E Depth m Time : 22 h—45 m Sep. 17th 1949					
0	28.2	18.26	4.41	610	1
10	27.99	18.26	4.37	560	7
25	27.24	18.31	4.64	670	2
50	24.41	18.66	4.23	560	1
75	22.55	19.04	4.04	670	12
100	18.71	19.12	4.76	830	12
150	16.33	19.11	4.80	1050	23
200	14.16	19.03	4.71	1220	44
St. 6 : 32°07, O′N 128°50, 3′E Depth 350 m Time : 1 h—50 m Sep. 18th 1949					
0	28.2	18.19	4.64	560	0
10	27.90	18.17	4.58	670	0
25	26.87	18.34	4.63	670	0
50	26.33	18.41	4.57	670	0
75	22.03	19.12	3.94	780	6
100	19.56	19.12	3.82	890	8
150	16.22	19.21	3.84	1170	22
200	13.51	19.12	3.62	1550	55
St. 7 : 32°04, 6′N 128°41, O′E Depth m Time : 4 h—00 m Sep, 18th 1949					
0	28.3	18.21	4.41	720	0
10	28.08	18.22	4.46	610	1
25	27.27	18.42	4.54	670	0
50	24.52	18.84	4.57	670	4
75	21.22	19.09	4.02	1050	10
100	19.41	19.17	3.80	1110	13
150	15.86	19.15	3.77	1220	25
200	12.99	19.03	3.79	1670	49
St. 8 : 32°00, O′N 128°24, 5′E Depth 138.1 m Time : 7 h—25 m Sep. 18th 1949 Wc 2 Transp. 20.8					
0	27.8	18.31	4.60	1000	2
10	27.27	18.30	4.56	670	3
25	27.12	18.42	4.60	610	1
50	25.35	18.53	4.62	670	3
75	23.17	18.85	4.36	940	9
100	20.43	19.10	3.94	1440	3

St. 9: 32°01, 6'N 128°20, 6'E Depth 145.9 m
Time: 8 h—45 m Sep. 18th 1949
Wc 2 Transp. 16.6

0	27.6	18.42	4.59	670	1
10	26.96	18.34	4.72	720	1
25	26.30	18.37	4.74	610	1
50	25.21	18.55	4.59	670	2
75	22.25	19.00	4.22	720	12
100	19.63	19.10	4.91	1220	24

St. 10: 32°08, O'N 128°14, 9'E Depth 153.3 m
Time: 10 h—35 m Sep. 18th 1949
Wc 2 Transp. 23.0

0	28.7	18.42	4.52	670	0
10	28.20	18.44	4.45	670	0
25	27.04	18.44	4.53	830	1
50	25.17	18.55	4.61	720	1
75	22.66	19.02	4.27	670	9
100	19.80	19.03	4.11	1440	13

St. 11: 32°15, 2'N 128°09, 5'E Depth 138.6 m
Time: 13 h—14 m Sep, 18th 1949
Wc 1 Transp. 22.0

0	28.7	18.53	4.48	670	0
10	28.52	18.53	4.62	720	0
25	28.01	18.63	4.56	830	0
50	25.43	18.83	4.68	830	2
70	21.59	19.10	4.06	830	1
100	19.81	19.10	3.81	1550	13

In this case of white water mass, P_2O_5 in the nonconservative properties in situ is likely a limiting factor for population growth of *Trichodesmium* sp., and on the contrary, a lowering of viscosity of the sea water can not be seen from Table 4. owing to that this white water appeared during the season of temperature maximum and in the waters of high salinity of the warm Tsushima Current branched off the Kuroshio. Accordingly, the viscosity factor can not be dealt in considering the causative factors.

4. Discolouration of *Rhizosolenia styliformis* **Brightwell** and *Rhizosolenia styliformis* var. *latissima* **Brightwell.**

Rhizosolenia styliformis played the part of appearance of white water mass in the Bay of Omura in January, 1949. Chemical Properties of this white water observed on January 28, 1949 are represented in Table 5. By means of this table, it is obvious that absorption of SiO_2 proceeded and gave rise to exhaustion of SiO_2. In spite of this, P_2O_5 is in normal concentration. In conservative properties of this white water mass, water temperature is 10.15–10.68°C and chlorinity 17.87–17.94 Cl‰. This water mass was vertically stable and severe animal exclusion took place.

Rhizosolenia styliformis var. *latissima* made monospecific population and changed water colour into pink in the waters adjacent to the east coast of Iki I. during May to June, 1955. Water temperature of this pink water mass observed

Table 5. Results of observation of white water mass discoloured by *Rhizosolenia styliformis* in January, 1949, in Omura Bay.

Observed layer (m)	Tw. °C	Cl ‰	SiO_2 mg/m³	P_2O_5 mg/m³	N_2O_3 mg/m³	Consumed O_2mg/l
St. 1. Depth 12.0 m, W.C. 4–5, Transp. 12.0 and far more						
0	10.15	17.87	11.0	44.4	2.7	2.2
5	10.28	17.94	94.4	55.6	5.3	1.4
12	10.20	17.91	38.5	26.7	3.3	1.2
St. 2. Depth 14.4 m, W.C. 4 (white), Transp. 14.4 and far more.						
0	10.50	17.91	22.0	33.3	4.4	1.4
5	10.18	17.88	11.0	37.8	3.3	1.3
10	10.23	17.92	tr.	26.7	2.7	1.5
St. 3. Depth 13.4 m, W.C. 4–5 (white), Transp. 13.4 and far more.						
0	10.68	17.79	tr.	33.3	2.2	2.0
5	10.50	17.90	tr.	40.0	3.3	1.1
10	10.42	17.90	tr.	33.3	3.3	1.3

on June 3 is 19.76–20.78°C and chlorinity 18.63–18.95 Cl‰ as shown in Table 6.

Table 6. Results of observatian of pink water mass off the coast of Iki I. in the Straits of Tsushima on June 3, 1955.

Observed layer		Observed station			
		1	2	3	4
0 m	Tw °C	20.6	20.6	20.6	20.6
	Cl ‰	18.82	18.63	18.81	18.80
10 m	Tw °C	20.13	20.15	20.25	20.78
	Cl ‰	18.92	18.72	18.82	18.86
25 m	Tw °C	19.96	19.76	20.28	—
	Cl ‰	18.95	18.90	18.89	—
50 m	Tw °C	20.27 (40 m)	19.19	20.34 (35 m)	—
	Cl ‰	—	18.96	18.94	—
Water colour		4	3–4	4	—
Transp.		15	18	15	—

Comparing differences of properties between white water and pink water, the latter is twice as high as the former in water temperature and chlorinity of pink water is about 1.00 Cl ‰ higher than that of white water.

On account of that the relationship between absorption rate of the nonconservative property and the morphological character of plankton may be considered, the author examined minute structure of the frustule of those plankton by the electron microphotograph as shown in Plate 1. Referring to the electron microphotograph, the author can demonstrate the minute structure of the frustule with special reference to those sculpturing. The intercalary band and the imbrication

line can be seen distinctively. *Rhizosolenia styliformis* has remarkable character that quadrilateral areola in network areolation of scalelike intercalary band.

Minute structure of *Rhizosolenia styliformis* var. *latissima* examined by the electron microphotograph are represented in Plate 1. There can be seen big and dull apical process and faint winglike expansion on apex of a cell. Network areolation seen and the shape of areola is benzene nucleus. Intercalary band narrow and imbrication lines and parallel.

Considering rapid growth of the red tide plankton from such areolation, one can assume that increase in rate of nutrient absorption of plankton corresponding to rising of viscosity of environmental sea water may take place.

5. Discussion.

There are many causative factors for the explosive population growth of marine plankton. Owing to some discolourations of sea water by plankton described above, it may be true that the limiting factor of population growth of plankton is not to be definite, and is to regard as environmental variables corresponding to species plankton and its ontogenic adaptation. For example, in the case of white water discoloured by *Rhizosolenia styliformis* in Omura Bay, SiO_2 seems to be a limiting nutrient, and for white water of *Trichodesmium* P_2O_5 is likely to be a limiting nutrient.

The author should like to appreciate that a condition of the discrete water mass proposed by Kierstead H. and L.B. Slobodkin (1953) and Slobodkin L.B. (1953) is need to cause the density growth of plankton in the given water mass. Accordingly, the density growth rate of plankton population K is obtained by the formula

$$\frac{r}{L}=K$$

where r is the intrinsic (autogenic) population growth rate of plankton and L is leakage. Then, the following condition is desired

$$\frac{r}{L}>\text{ I and far more.}$$

Moreover he has demonstrated by such biotic structure of diatoms as network areoalation of the frustule, that absorption rate of nutrients in the cell is raised by a lowering of viscosity of environmental sea water.

Munk W.H. and G.A. Riley (1952) discussed that absorption rate of nutrients in the plankton cell varies with its shape and a lowering of viscosity of environmental sea water. The author may recognize that the theory of absorption rate is able to be adopted in considering physiological-ecological factor for a rising of population growth rate of plankton. But in consideration of onset of the red water, the nutrient factor has the secondary meaning, and the author may be able to assume that the time rate of increase of solar radiation energy owing to several cases of the red water off western Japan is a causative factor.

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EXPLANATION OF PLATE I

Electron micrographs showing fine structure of skeleton of *Rhizosolenia styliformis* (white water plankton) collected on January 25, 1949 in Omura Bay, and of *Rhizosolenia styliformis* var. *latissima* (pink water plankton) collected on June 3, 1955 in the waters adjacent to Iki I. off western Japan.

Figs. 1—3: *Rhizosolenia styliformis*
Figs. 4—6: *Rhizosolenia styliformis* var. *latissima*

Figure 1. Apex of a cell showing the apical process and faint winglike expansion. X3000

Figure 2. Side-ventral view of calyptra. X2000

Figure 3. Side-ventral view of part of a cell showing scalelike intercalary bands and imbrication lines, especially areolation of the intercalary band. X2000

Figure 4. Apex of a cell showing the apical process and faint winglike expansion. X2000

Figure 5. Ventral view of calyptra showing intercalary bands, imbrication lines and especially areolae representing benzene nucleus. X2000

Figure 6. A part of girdle showing intercalary bands and parallel imbrication lines. X2000

PLATE I

Figure 1. X3000

Figure 4. X2000

Figure 2. X2000

Figure 5. X2000

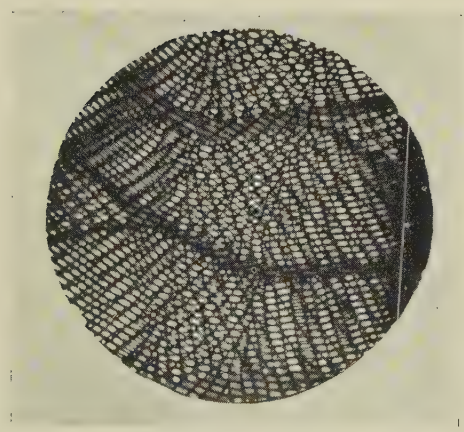

Figure 3. X2000

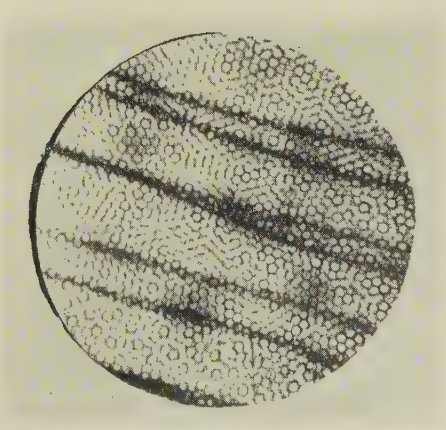

Figure 6. X2000

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On Some Recent Fish Otolith

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With the purpose of studying the fish otoliths collected from the Cenozoic deposits of several places in Japan, the writer has found it necessary to make an investigation of those of the living fish fauna of Japan, so that comparative morphology can be undertaken. This has been found to be important because our knowledge on the ear bones of living fishes is limited to only several genera and species, which are found in publications related to fisheries. In fisheries the otoliths are used for age determination, whereas in the case of fossils the writer desires to use them if possible, as data for paleoecological analysis of the rocks entombing them.

Owing to that the Recent fish fauna of Japan is a very rich one, the writer will describe and illustrate the ear bones of the different species in a series of reports of which the present one is the first to those planned to be published. This reports treat several species of otoliths which were extracted by the writer from the fish from several places within Northeast Honshu, Japan. The generic and specific names of the fish were determined by specialists and then their ear bones were extracted. These specimens are all registered and preserved in the collection of the Department of Geology, Faculty of Education, Tohoku University, Sendai.

Here the writer expresses his thanks to Dr. Etsuro Hirai of the Asamushi Biological Station of the Tohoku University for his kindness during the writer's stay at the station. He also thanks Messrs. Koichiro Masuda, Hideo Mii and Jun Kataoka for their assistances in many ways.

Arctoscopus japonicus (Steindachner) Figs. 3, 4.

Shape subcircular, outer side nearly straight, slightly convex, inner side nearly flat, only slightly concave; dorsal border highly arched, provided with ten denticles of which the anterior-most and posterior three are largest and separated from intermediate ones, intermediate ones close-set and well rounded but fused together ventrally, posterior-most slightly curved posteriorly, anterior-most acutely directed posteriorly and forming with dorsal border of anterior projection an acute angle; anterior projection long and finger-like, its dorsal border nearly smooth and gently ascending dorsally without denticles, anterior extremity bluntly rounded and gradually passing into nearly flat ventral border which has one large though flatly rounded and two small denticles in the middle part; posterior extremity of ventral border swollen into one very large ill-defined denticle; surface of inner

side swollen ventrally but gradually lessening in thickness dorsally; outer side nearliy flat, incised transversally with ill-defined groove extending from behind anterior projection to nearly in front of outer side of posterior-most denticle of dorsal border; ventral half of outer side thickened and provided with two distinct concave grooves of different length, the ventral being longer than the dorsal. Nucleus, growing and resting zones indistinct. Length ca. 7mm, width ca. 5mm.

Locality.-Off Akita City, Akita Prefecture. Reg. No. P-27.

Remarks.-Comparing the ear bones of the fish of the named species from the large bay of Hachro-gata with those from off Akita City, several outstanding differences are noticed. Here it must be stated that the bay of Hachiro-gata contains a peculiar fauna owing to the difference in distribution of salinity. The inner area of the bay near the mouth possess a typical marine fauna while the area in the farthermost part of the bay contains a brackish to nearly freshwater fauna. This contrasting ecological condition within the bay may have had influence on the fish living there. Although the external morphological characters of this fish from the open sea and Hachiro-gata may be quite the same, there remains a probability that the difference in the characters of their otoliths may be important criteria for specific, subspecific or variety separation, at least based upon their ear bones. In fossil specimes only the characters of the otoliths are used for specific discrimination. Therefore, whether the distiction be of specific, subspecific or varietal value, the writer considers it best to hold the otoliths described below as separate from the species *Arctoscopus japonicus* (Steindachner), and for this reason he gives it a new name.

Arctoscopus japonicus hachirogatensis Hatai, n. subsp. Figs. 7, 8.

Shape fan-like with broad base, outer side nearly flat only slightly convex ventrally, inner side swollen, only slightly concave at anteroventral part: dorsal border expanded fan-like, with about eight roundly flat-topped denticles of varied width, generally with about three broad ones and fine small ones, abruptly narrowing ventrally into broad ventral lower half: anterior projection protruding finger-like, smooth on dorsal and ventral borders, its extremity directed ventrally, forming narrowly acute angle with tapering antero-dorsal margin; ventral border only slightly concave, nearly smooth, with only several weakly developed denticles; postero-ventral extremity slightly protruding, broadly rounded, forming a single large, smooth, broadly rounded denticle or incised with a groove which maked it appear as two broad denticles. Outer side somewhat roughened, transverse groove indistinct, divided into two parts of dorsal and ventral by indistinct transverse partition; dorsal half with slit rays of denticler of dorsal border all directed medially but terminating before reaching indistinct transverse partition; lower or ventral part also somewhat roughened, especially at ventral-most part due to development of slit rays. Nuclueus, growing and resting zone indistinct. Length

ca. 6 mm, width ca. 4.2 mm.

Locality.-Hachiro-gata, Akita Prefecture. Reg. No. P-116.

Remarks.-Compared with *Arctoscopus japonicus*, the otolith of the subspecies has the postero-ventral border more protruding, a fewer number of denticles on the dorsal border, the anterior projection directed ventrally at its extremity, stronger and more extensive slit rays on the outer side and a slightly different shape in general.

By the mentioned characteristics the subspecies can be distinguished from the species, at least by the ear bones. Since fossil specimens are descriminated only by the otoliths, it seems worthy to separate the present specimens from the species so that studies on the fossil specimens can be advanced.

Muraenesox cinereus (Forskal) Figs. 15, 16.

Shape lanceolate, outer side almost flat, only slightly convex, inner side only slightly concave, nearly flat: dorsal border posterioly stepping down to posterior dorsal flattened, short border, anterioly forming nearly vertical angle with anterior projection and there provided with one shape denticle which make termination of dorsal border anteriorly, elsewhere very broadly arcuate and almost smooth; anterior projection short, protruding triangularly, smooth on both dorsal and ventral borders; ventral border broadly bow-shaped, almost smooth, its posterior extremity squarely to brordly rounded. Outer surface somewhat roughended, with transverse groove oblong in shape, with sides nearly parallel with the ventral side steeper than that of the dorsal, confined to the middle part, not extending to either posterior or anterior margins. Nucleus narrowly lanceolate. Growing and resting zones indistinct. Length ca. 7 mm, width ca. 3 mm.

Locality.-Off Kinkazan, Miyagi Prefecture. Reg. No. P-3.

Remarks.-Commonly called *Hamo* in Japan, the otolith is characterized by its nearly smooth dorsal and ventral borders, lanceolate shape, abrupt terminations of the dorsal border anteriorly and posteriorly, the short and triangular anterior projeciion, and oblong but not very extensive transverse groove.

Sebastodes güntheri (Jordan and Starks) Figs. 9, 10.

Sharp transversely sublanceolate, outer side convex, inner side concave; dorsal border serrated with denticles at antero-dorsal end just before abrutply passing into nearly flat but denticulated dorsal border of anterior projection; anterior projection with three denticles on its antero-ventral part; ventral border unevenly broadly concave; posterior side oblique, bluntly rounded, one large denticle at posteroventral corner, several smaller ones above. Nucleus large, transversely oval in shape. Growing zone slightly broader than resting zone; resting zone narrower on ventral than on dorsal margin. Inner surface roughened. Outer side convex, roughened slightly, incised with transverse groove, flat-bottomed,

extending from behind anterior projection posteriorly to near postero-ventral border where it becomes indistinct, ventral side of groove nearly parallel with ventral border, dorsal border broadly sinuous, its sides sharp, appearently smooth. Length ca. 8 mm, width ca. 4.5 mm, width of groove ca. 1 mm.

Locality.-Asamushi, Mutsu Bay, Aomori Prefecture. Reg. No. P-57.

Remarks.-This species is commonly called *Sorafuki* in Mutsu Bay and *Mebaru* in Central Japan. In living state it is interesting to notice that it keeps its body in an oblique position whether at rest or in floating. It lives in groups and in depths generally of nine or more fathoms near rocky coasts.

Sebastodes tokionis Jordan and Starks Figs. 11, 12.

Shape transversely sublanceolate, outer side convex; inner side concave; dorsal border with denticles at anterior sloping part and on posterior half, few but distinct; anterior projection prominent, thickened, merging into dorsal border rather sharply, gradually passing into ventral border; ventral border broad, slightly denticulated at posterior one fourth, elsewhere only fainly denticulate; posterior side abrutply truncated, with a lower strong and several weaker upper denticles which are best developed on postero-dorsal border. Nucleus transversely diamond shaped. Growing and resting zones distinct, the latter broader posteriorly than eisewhere, bnt the former becoming narrower outwards. Inner surface wavy but smooth, not roughened. Outer surface with incised groove extending transversely from behind anterior projection posteriorly to postero-ventral protuberance, distinct, nearly sharp and smooth, nearly parallel; outer surface not roughened by wrinkles but smooth and somewhat wavy. Length 7.0 mm, width 3.5 mm, width of groove ca. 1 mm.

Locality.-Asamushi, Mutsu Bay, Aomori Prefecture. Reg. No. P-56.

Remarks.-Compared with the otoliih of *Sebastodes güntheri* (Jordan and Starks), the present one has a narrow nucleus, more acture anterior projection, less number of denticles on the dorsal border and smoother outer surface. The present one is also distinguished from the ear bones of *Sebastodes schlegelli* (Hilgendorff) by means of the shape and by the strength of the denticles.

This species is called *Akamebaru* in Mutsu Bay and lives among sea weeds at a depth of less than fifteen fathoms and is often caught by fishermen's nets. Whether this species lives at depths exceeding fifteen fathoms the writer has no information. However, the adult is though to live at greater depths.

Sebastodes schlegellii (Hilgendorff) Figs. 1, 2.

Shape transversely oval, outer side convex, inner side concave; inner side concave; dorsal border finely denticulate, with two large denticles at antero-dorsal and postero-dorsal extremities; anterior projection not sharp, denticulated, with one large denticle at junction of antero-dorsal and posterior part of anterior pro-

jection; ventral margin denticulated at its anterior and posterior parts, nearly smooth in middle; postero-ventral part broken into large denticules, the largest at extremity and posterior borders; denticle at posterior border largest and bifurcated. Inner side roughened by growing and resting zones. Nucleus transversely oval. Outer side more or less roughened, with transverse median groove extending from behind largest denticles at posterior part of anterior projection, posterioly to postero-ventral corner. Ventral side of groove parallel with ventral border, dorsal side sinuous, both anterior and posterior parts of groove contracted, rather abruptly widening just before contracting at postero-ventral side. Sides of groove not roughened, sharp but not deep, flat bottomed. Length ca. 10 mm, width ca. 5 mm, width of groove 0.5–1 mm.

Locality.-Asamushi, Mutsu Bay, Aomori Prefecture. Reg. No. P–55.

Remarks.-The otolith of this species can be distinguished from those of *Sebastichthys trivittatus* and *S. pachycephalus* by having more strongly denticulated border, stronger denticles at postero-ventral extremity and by the groove of the outer side being of different shape. Compared with the ear bones of *Sebastodes tokionis* and *S. güntheri* that of *S. schlegellii* has stronger denticulated borders, less defined anterior projection, and more outstanding denticle at postero-ventral extremity. The shape of the grooves of the above mentioned three species are similar. The shape of the nucleus differ somewhat, that of *S. schlegellii* being most oval in shape. This species in called *Kurosoe* in Mutsu Bay and lives above rocky bottoms.

Sebastichthys trivittatus (Hilgendorff) Figs. 5, 6.

Shape transversely oval, outer side convex, inner side concave; dorsal border convex posteriorly, concavely sloping anteriorly; anterior projection pointed, its extremity rounded; ventral border broadly rounded; posterior side more broadly rounded than anterior; five resting zones and five growing zones; nucleus transversely oval. Inner surface smooth, ihe outer provided with rather deep, flat-bottomed groove extending from anterior projection posteriorly to near posterior margin where it becomes indistinct, measuring 1 mm at broadest part. Dorsal border with low, broad to narrow denticles. Ventral border uneven, but without distinct denticles except at postero-ventral part where two exist, the anterior one is broad and low and the posterior one projects postero-ventrally, being flattened mammelon shape. Posterior side with one broad denticle. Length 9 mm, breadth 5.5 mm, width of groove 1 mm.

Locality.-Asamushi, Mutsu Bay, Aomori Prefecture. Reg. No. P–59.

Remarks.-This species when full adult attains about 180 mm in length and commonly lives in the seas of northern Japan. It is not rare in Mutsu Bay and although not commonly found on the market, it is used for food. It is caught by the fishermen at shallow depths, that is to say, generally below four fathoms

and commonly around the seven to nine fathoms region.

Sebastichthys pachycephalus (Temminck and Schlegel) Figs. 13, 14.

Shape transversely nearly lanceolate, outer side convex, inner side concave, dorsal border irregularly and broadly convex, straight but irregulary sloping into anterior projection which is acute, bluntly rounded; ventral border nearly straight; posterior side blunt, indented in its middle part. Nucleus obliquely oval in shape. Inner surface roughened by wrinkles caused by growing and resting zones, otherwise smooth. Outer side with narrow, flat-bottomed groove extending from behind anterior projection to posterior indentation, its lateral sides more or less roughened, measuring about 1.5 mm in maximum breadth. Dorsal border with a few denticles on part sloping towards anterior projection and one on its middle part; anterior projection with several small denticles, ventral border finely serrated, with large denticles; posterior border with two denticles formed by the median indentation. Length 6.5 mm, breadth 3.0 mm, width of groove 1.5 mm.

Locality.-Asamushi, Mutsu Bay, Aomori Prefecture. Reg. No. P-58.

Remarks.-Compared with the otolith *Sebastichthys trivittatus* (Hilgendorff), the present one has a more lanceolate shape, shows less convexity, has fewer denticles on the borders, lacks a prominent mammeliform denticle at the postero-ventral part, and the lateral sides of the groove are not roughened.

Whether specific distinction among the species in the genus is possible must be reserved until more material has been studied. However, at the present stage of study there can be found important distinctions among the strength, number and position of the denticles, shape and strength of the groove on the outer side, shape of the otolith and shape of the nucleus.

Funds necessary for the present work was received from the Saito Ho-on Kai Foundation, Sendai, Japan. The writer wishes to express his appreciation to the authorities of the Foundation for the grant.

Explanation to Figures 1–16. (All enlarged three times)

Figs. 1–2, *Sebastodes schlegelii* (Hilgendorff). 1–inner view, 2–outer view. Figs. 3, 4, *Arctoscopus japonicus* (Steindnacher). 3–outer view, 4–inner view. Figs. 5, 6, *Sebastichthys trivittatus* (Hilgendorff). 5–inner view. 6–outer view. Figs. 7, 8, *Arctoscopus japonicus hashirogatensis* Hatai, n. subsp. 7–outer view. 8–inner view. Figs. 9, 10, *Sebastodes guntheri* Jordan and Starks. 9–outer view. 10–inner view. Figs. 11, 12, *Seastodes tokionis* Jordan and Starks. 11–outer view. 12–inner view. Figs. 13, 14, *Sebastichthys pachycephalus* (Temminck and Schlegel). 13–inner view. 14–outer view. Figs. 15, 16, *Muraenesox cincereus* (Forskal). 15–outer view. 16–inner view.

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Studies on the Removing Scale from Sea Water or Natural Brine.

By

Jinkichi Yoshimura

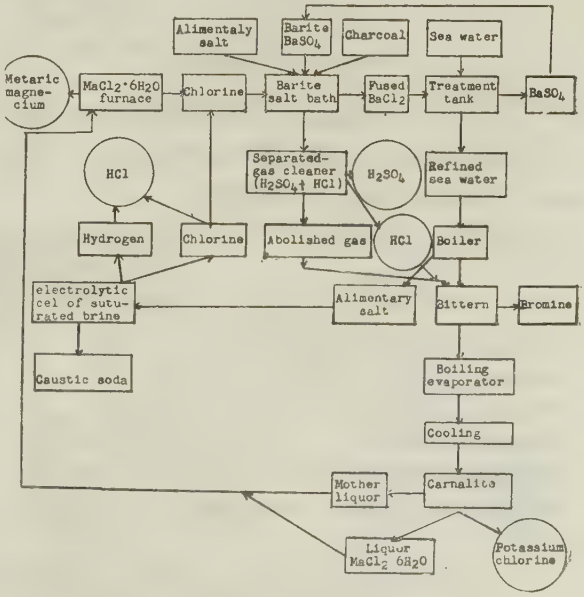
(Salt and Camphor Bureau, Japan Monopoly Co-operation)

In manufacturing salt by boiling sea-water or natural brine, so called "scale" containing as principal ingredient calcium sulfate precipitates grows on heated surface which interrupts the transmission of heat, makes the equipments fragile, and further interrupts smooth operation, accordingly degrading the quality of products. The treatment for preventing scale, which has brought a sufficient result in our experiments, is to make SO_4 (in $CaSO_4$ and $MgSO_4$) react upon soluble Barium salts such as $BaCl_2$ and obtain in deposit gross crystal of $BaSo_4$, which is insoluble either in the sea-water or brine, etc. Then $BaSO_4$ will be separated from the sea-water or brine and there will be no fear of adhesion of scale. Moreover, all the defects mentioned above will be prevented and we can take advantage of rationalizing the use of brine ingredients, which are notable characteristic of this treatment.

In order to make successful the above mentioned treatment, it is necessary to enlarge the crystal of $BaSO_4$ and to facilitate its separation. At the same time, it is also necessary to recover economically $BaCl_2$ from the separated $BaSO_4$.

As we have succeeded to obtain good results in our laboratory experiment, we are now proceeding on a medium scale test for the purpose of industrializing the method.

This method is illustrated in the following system which has a characteristic of producing two by-products of free H_2SO_4 and free HCl separately after the recovery of $BaCl_2$ from $BaSO_4$.



1) RECOVERY OF $BaCl_2$

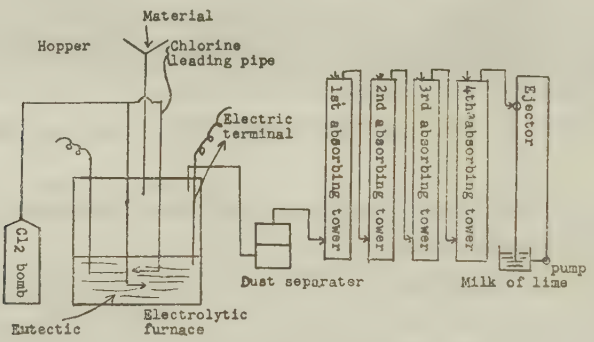
Throw the mixture of NaCl and $BaCl_2$ at the ratio of 9 : 1 in a electrolytic furnace together with "Criptol" and keep the temperature at 800° C, then 1 kg of the mixture of NaCl, $BaSO_4$ and charcoal powder will be thrown in the furnace once every minutes, while Cl_2 gas is being passed through the bottom of the furnace and exhausted gas therefrom is removed by "ejector".

In the recovery test of this year, emphasis has been placed upon the decision of optimum conditions and we were able to get the following results.

Item	Results	Item	Results
Average voltage	37.7 volt	Average power used in furnace	9.95 K.W.
Maximum //	55.0 //	Velocity of increasing temperature in furnace (to 800° C)	30.8° C/hr.
Minimum //	30.0 //	Average power used in absorbing tower	8.08 K.W.
Average Current	189.1 Amp.	Quantity of chlorine gas lead in	3.9 kg/hr.
Maximum //	250 //		
Minimum //			

We are going to get data by normal operation of the furnace.

EQUIPMENT OF RECOVERY TEST



RESULTS OBTAINED BY MEDIUM SCALE TEST

The test was conducted by the same method as that of the previous year under the following conditions :

Item	Test of measuring specific loss ($BaCl_2$ used)		Principal test ($BaSO_4$ used)	
	Mean Value	Standard declination	Mean Value	Standard declination
Temperature °C	785	40	835	21
Voltage V	26	2	27.5	4.5
Electric current A	274	8	235.6	1.5
Electric power KW	11.6	0.8	9.7	1.0
Equivalent conductivity Ω	10.4	0.7	9.0	3.0
Quantity of chlorine consumed kg/hr.	—	—	3.45	0.36

Test of specific loss ($BaCl_2$ is used) Recovery ratio of $BaCl_2$ 88.3 ± 1.7% Recovery test ($BaSO_4$ is used) 69.1 ± 1.1%

Recovery ratio seems to be able to draw near to 100% by preventing the scattering of materials and operating continually the furnace.

2) REFINING AND CONDENSING TEST OF SEA-WATER AND BRINE.

Basic test has already been conducted as mentioned above and a medium scale test has also been conducted.

Pour $BaCl_2$ brine into the reaction tank with the equal quantity of brine from salt field and at the same time stir the liquid and let out exhaust from the bottom of the tank.

We obtained as a result, large crystals (50–100μ) which can easily be dehydrated with centrifugal separator. Relations between desulpharized ratio and its items are shown below:

$$Z = 0.078 + 0.015x - 0.003y$$

$$Sz \cdot xy = 0.0093$$

z: SO_4% contained in de-SO_4 brine/SO_4% contained in original brine

x: $BaCl_2$% contained in $BaCl_2$ brine/SO_4% contained in original brine

y: Reacting temperature (°C)

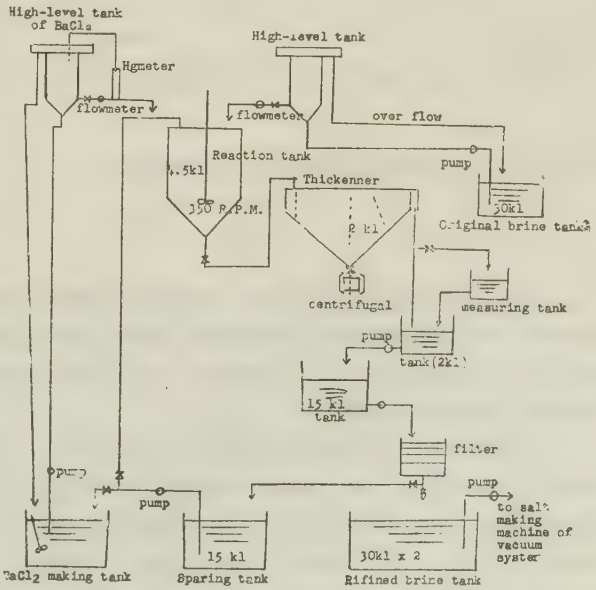
$Sz \cdot xy$: Standard error of regression equation

In a de-SO_4 test with $BaCl_2$, we were able to experiment condensation of mother liquor and bittern in order to know how the temperature affect its condensation and the density of disposed liquor.

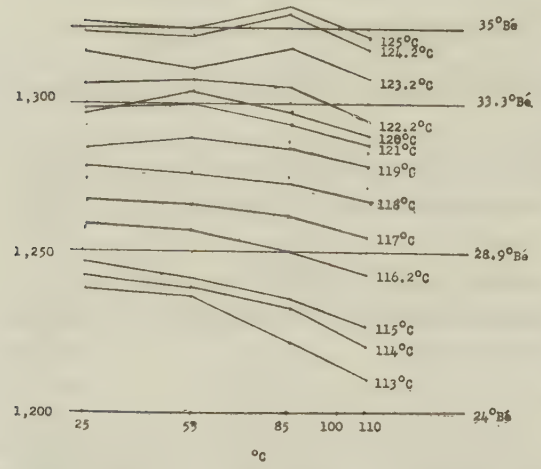
In desulfating of 16.3° Bé salt-field brine with $BaCl_2$ brine, we condensed it to 26° Bé at first, and condensed it further to 113°C–125°C at boiling point. Then analysed and measured its density and temperature at each boiling point in keeping each sample at 85°C, 55°C, 25°C for 5 hours.

From the above experiment, we can say that if the limit of condensation of mother liquor is reached at a point where maximum quantity of NaCl is obtainable and no more precipitation of KCl is found, then 30.2 Bé (108.8°C) at the boiling point ot 118°C and density of 31.9° (25°C) at cooling time is

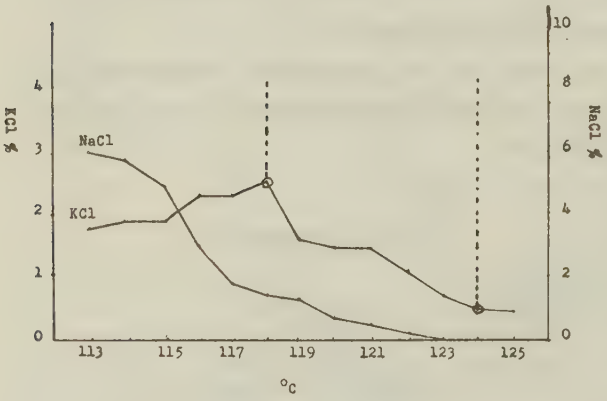
TEST EQUIPMENTS



RELATION BETWEEN DENSITY AND TEMPERATURE



TENDENCY OF NaCl, KCl



the limit of condensation. We decide the limit of condensation of de-SO_4 bittern about 124°C from a trend of KCl.

OTHER TEST

1) TEST ON MAGNESIUM HYDROXIDE

by Junkichi Yoshimura
Masao Ayai

It became evident that the continual reaction of $Mg(OH)_2$ crystal enlarged granules and decreased quantity of sedimentation. As for the solution of $CaCl_2$, the thinner the better until one hour and a half is reached after the beginning of its reaction. After the lapse of more than 2 hours there is not much difference, and the higher the density of $MgCl_2$ solution, it becomes worse. For 2-3 hours, crystalization increases gradually and almost no change was observed thereafter.

2) TEST ON MAGNESIUM HYDROXIDE

by Masaichi Nishida
Masao Ayai

NH_4Cl was added in order to obtain larger crystalization of $Mg(OH)_2$. The result was remarkable, especially when an equivalent of 100%-80% of bittern is added to milk of lime. However, its effects gradually decreased from an equivalent of 60-40% bittern.

Concerning the manufacture of $Mg(OH)_2$ containing less CaO, which is related to quality, we tested with washing and filtration methods. As for OH', good result was obtained in the case other than equivalent ratio of 100%. There was not much difference in the effect of density of milk of lime. An application of filtration brought the best result; however, if the well water is used the result showed 1% less in comparison with $CaO/MgO = 7\text{-}10\%$.

3) TEST ON MANUFACTURE OF GYPSUM

by Masaichi Nishida
Tominari Maeda

This is the method of manufacturing gypsum from sodium sulphate bittern mother liquid and calcium chloride.

1) If we make $(SO_4'')X(Ca'')$ smaller in value, a good result will be obtained even if high density bittern and calcium chloride are used. In the case of sodium sulphate PH=6–7, 60°C, and in the case of bittern mother liquid, 40°C were the the optimum conditions respectively.
Addition of sodium citrate brought an effective result.

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On the Electrolysis of Dilute Solution of Sodium Chloride

— Electrolysis by Diaphragm-Amalgam Type Process. —

By
Taizo Kume and Masaru Okada
(Faculty of Engineering, Tokushima University)

INTRODUCTION

Electrolysis of sodium chloride solution by the mercury process is almost exclusively applied to concentrated (or saturated) NaCl solution, the amalgam being circulated from the cathode room to the denuding room. But, recently a process by which electrolysis and denuding are simultaneously carried out at the same place by using a suitable diaphragm, say, "diaphragm amalgam type" has been devised. Characteristics of this new process consist in the possibilities to cut down a great deal the necessary quantity of mercury on which the cost of apparatus is greatly dependent and to avoid the use of circulating mercury and so on. This new method, however, is not generally applied, especially to the dilute solution.

Basic research of the electrolysis of dilute NaCl solution has been carried out by the diaphragm type method, whose results will contribute to the direct electrolysis of sea water.

EXPERIMENTS

Preparation of samples: Mercury was prepared by distilling the material twice after the usual chemical purification. Sodium amalgam was prepared by cutting some pieces of metallic sodium together with mercury at about 60°C in a vessel kept free from air by liquid paraffin and kept in a stream on nitrogen gas and the concentration of the amalgam thus prepared was determined by treating with hydrochloric acid and subsequent back titration by sodium hydroxide.

Appratus: Diagrams of the apparatus are shown in Figs. 1 and 2.

Fig. 1 shows the electrolysis-cell. C is a diaphragm of biscuit upon which is placed 100 g of mercury, 0.58 cm thick, and 2000 ml distilled water.

In order to accelerate the reaction velosity of amalgam with water, a carbon plate with many holes bored so as to make it easy for hydrogen bubbles to escape, was placed in close contact with mercury. The carbon plate was used as the anode, separated by parchment paper from the electrolyte in the vicinity of the cathode so as to keep substances originated from chlorine gas evolved at the anode.

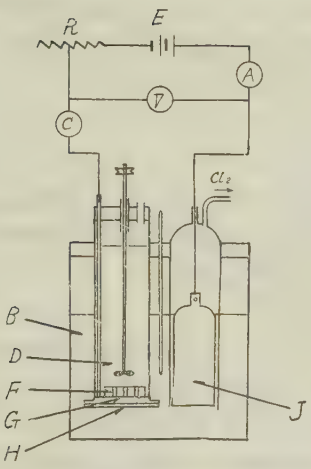

Fig. 1.

A: Ammeter
B: 3% NaCl Solution
C: Coulometer
D: Denuder Section
E: Battery
F: Denuding Plate (Graphite)
G: Cathode (Mercury)
H: Diaphragm
J: Anode (Graphite)
V: Voltmeter

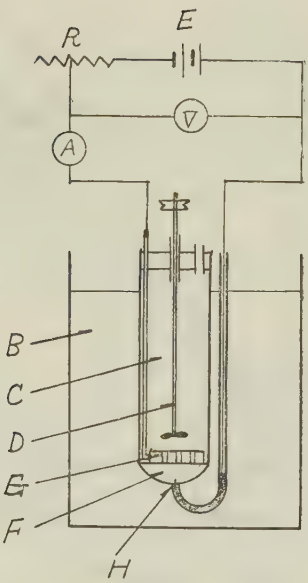

Fig. 2.

A: Ammeter
B: Thermostat
C: Denuder Section
D: Stirrer
E: Battery
F: Natrium Amalgam
G: Denuding Plate
H: Pt-lead
V: Voltmeter
R: Resistance

3 liters of 3% sodium chloride solution was used as electrolyte.

Fig. 2 shows the apparatus of deamalgamation with application of voltage. Certain amounts of mercury and water were put into the reaction vessel. The carbon plate was immersed into the mercury, various voltage being applied between the two.

EXPERIMENTAL RESULTS

(1) Electrolysis.

Experiments were carried out with the apparatus as shown in Fig. 1. The results are as follows:

According to Potter and Bissio (*) the temperature gradient of operating voltage was constant for any current density. But in the present experiment of dilute solution, the temperature gradient of operating voltage appears to decrease with temperature and to be constant for current density. It is natural that the current density being constant, the higher the temperature, the lower the operating voltage when the current density is constant.

(*) Chas Potter and A.L. Bissio, J. Electrochem. Soc., 101, 158; 1954.

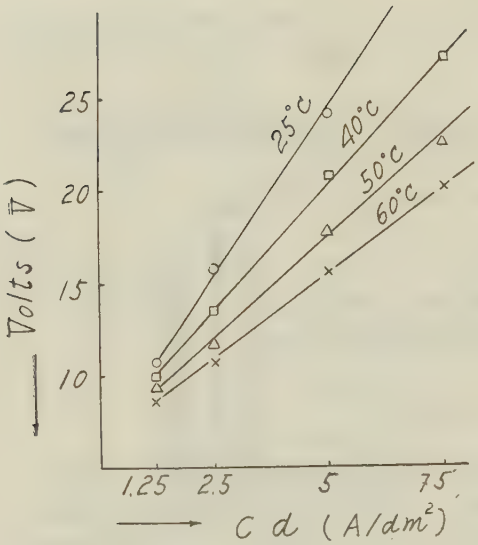

Fig. 3

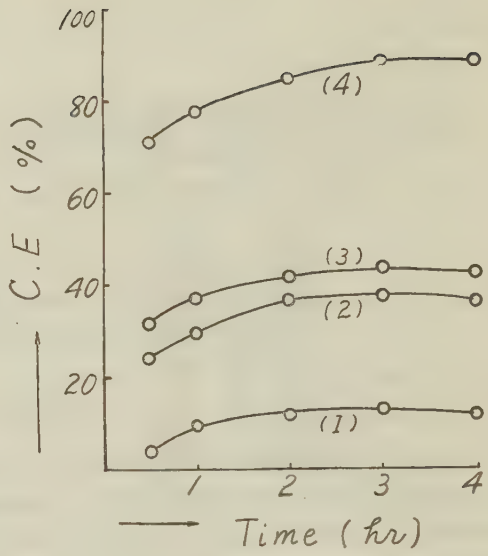

Fig. 4

Fig. 4 shows the variation of current efficiency with time at constant current density (5 A/dm^2) and at a constant temperature (25°C). So-called current efficiency (C.E.) was calculated from the concentration of sodium hydroxide solution, which had been produced by both disintegration of Na-amalgam deposited at the cathode, and theoretical quantity of sodium hydroxide measured by the copper coulombmeter.

Curve (1) referred in the run without denuding plate of carbon indicates very low C.E., which is considered to be caused by the small velocity of the reaction of amalgam with water.

Curve (2) shows the case when chips of carbon with diameter of about 6 mm are placed on the surface of mercury.

Curve. (3) is the case in which there was a carbon plate floating on the mercury. Though in curves (2) and (3) their C.E.'s somewhat increase in comparison with curve (1), these values are still lower than those of curve (4) where carbon plate is in close contact with the mercury, Thus, the large denuding velocity is obtained and consequently high C.E. is effected by sufficient contatact of the carbon with the mercury.

Along the curve (4) the concentration of sodium amalgam ranged from 0.002 to 0.005% in 4 hour electrolysis. This fact means that no sooner sodium amalgam had been produced than it was deamalgamated by water.

Current efficiency increases gradually with time for about 1½ hours. This fact can be interpreted as follows. In the initial step of electrolysis the rate determining step of deamalgamation may be considered as a chemical reaction, and the gradual stoppage retard of the concentration of amalgam with time is caused

by the smaller velocity of the chemical reaction than that of the electrolytic deposition of amalgam. As the increasing concentration gives rise to an acceleration of deamalgamation and, so current efficiency increases steadily.

As for the gradual drop of current efficiency from 3 to 3½ hours, which may be caused by the concentration of sodium hydroxide solution, a discussion will be made later.

Fig. 5 shows variation of the concentration of sodium hydroxide with time in the electrolysis of various current densities at a constant temperature (25°C). All these curves are almost linear except in their initial and final stages. These deviations from linearity may be explained by similar considerations mentioned above.

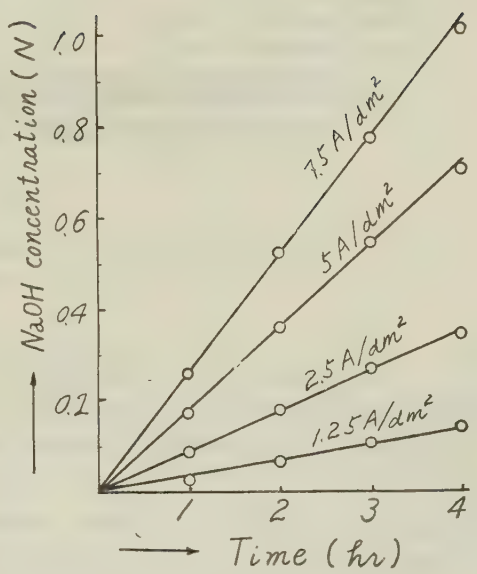

Fig. 5

Fig. 6 shows the relation of current efficiency with time at a constant current density (5 A/dm²) of various temperatures. It is obvious from this figure that the lower the temperature is, the higher current efficiency is obtained and that it is preferable to make electrolysis at higher temperature as is seen from Fig. 3.

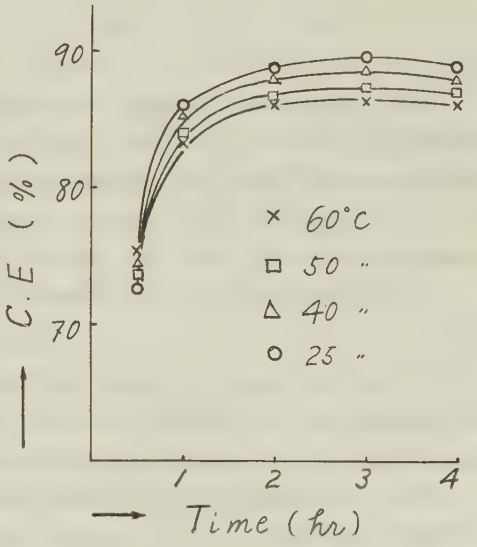

Fig. 6

Fig. 7 shows the relation between C.D. and C.E. The figure indicates that the higher the C.D., the higher the C.E. It may be that the higher the current density is, the higher the hydrogen voltage of amalgam cathode is and so sodium ion in the electrolyte becomes easier to discharge.

(II) Deamalgamation by the Application of Voltage.

Experiments were carried out with the apparatus illustrated in Fig. 2. The results are summarized in Table 1.

Table 1

Applied Voltage (V)	0	0.5	1	2	5
Time spent for Complete Deamalgamation (Min.)	32	14	7	5	1-1.5

where, concn. of amalgam : 0.194%, quantity of amalgam : 272 g., water for deamalgamation : 150 ml., temperature : 20°C, contact surface of carbon and amolgam : 20 cm².

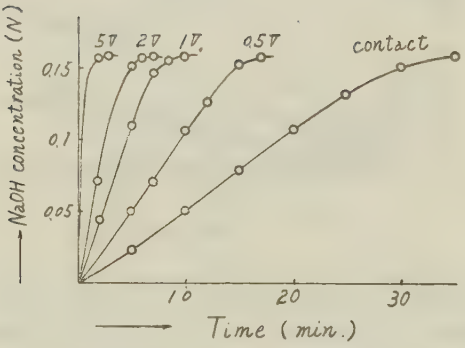

Fig. 7.

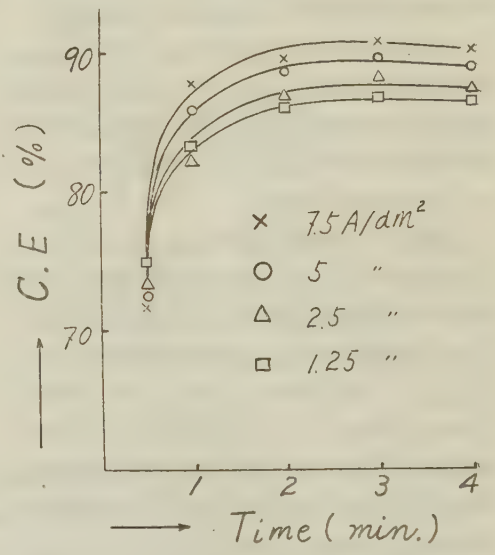

Fig. 8.

Fig. 8 show the variation of concentration of NaOH with time i. e. the deamalgamation rate. It is seen from the figure that the deamalgamation proceeds almost linearly with time, getting near the equilibrium state. From Table 1, it is obvious that the application of voltage gives rise to a speedy increase of deamalgamation rate, while the rate is very slow when no voltage is applied.

Further researches are in progress.

SUMMARY

In the electrolysis of dilute NaCl solution by diaphragm amalgam type method, the higher the temperature, the lower the operating voltage, that is, the operating voltage can be descended with rising temperature.

By utilizing the deamalgamation plate, current efficiency of 87-90% can be obtained and high current density affords high current efficiency. Accordingly, it is more favorable in dilute NaCl solution to electrolyse at high temperature and current density than otherwise.

By means of deamalgamation with application of voltage, deamalgamating rate is found to be remarkably accelerated and yet passible to control it at will.

The author wishes to express his appreciation to Prof. M. Ishibashi for his kind advice to this research.

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Quantitative Analysis of KCl and NaCl Mixtures with the X-Ray Spectrophotometer

By
Shiro Takashima, Yuji Hagino and Genzo Hashizume
(Central Research Institute of Industry, Hyogo Pref)

INTRODUCTION

The study of the quantitative analysis of crystalline powder mixtures was performed by many workers owing to the advent of Geiger-Counter X-ray spectrometer.

We performed the standard measurement of KCl and NaCl mixtures, studied the accuracy of this method and researched into the more accurate technique to apply the method to the analysis method in the sea-salt industry.

The apparatus used is Geiger-Counter X-ray spectrometer by Seifert Co.

The draw-up of the calibration curve I_{KCl}/I_{NaCl} vs. W_{KCl}/W_{NaCL}. We mixed up very pure KCl and NaCl at various rate, measured the intensity ratio (I_{KCl}/I_{NaCl}) of the 3.13A KCl and 2.81A NaCl maxima in the range of the weight ratio 0.05–10, and the intensity ratio of the KCl 3.13A and NaCl 3.25A in the smaller range than the weight ratio 0.05 and then drew up calibration curve (Fig. 1 and Fig. 2).

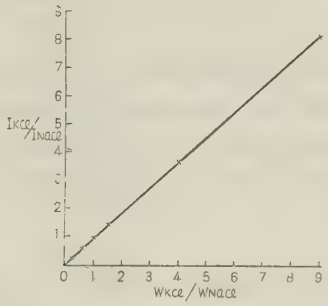

Fig. 1.

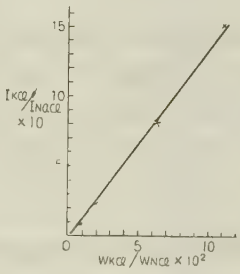

Fig. 2.

Source of Errors

1) The analysis of error-source

The variance σ^2 of measured values results in the variance σ_E^2 owing to technical errors, the variance σ_M^2 of errors of measured technique, and that σ_S^2 of errors of the inhomogeneity of the sample-mixing. Therefore, σ^2 is given by the following Eq.

$$\sigma^3=\sigma_E^2+\sigma_M^2+\sigma_S^2$$

Table I

I_{KCl}/I_{NaCl}	
Same surface of Sample	Different surface of Sample
0.91	0.80
0.90	0.97
0.91	0.89
0.92	1.05
0.91	0.93
0.90	0.97
0.91	0.90
0.91	0.86
0.91	0.91
0.91	0.89
Mean value 0.91	0.91
Variance 0.000033	0.0049

Table II

I_{KCl}/I_{NaCl}	
2 mm Slit Width	0.5 mm Slit Width
0.84	0.81
0.99	0.98
0.91	0.82
0.85	0.90
0.98	0.94
0.90	1.06
0.92	0.98
0.95	0.91
0.91	0.87
0.93	1.06
0.92	0.92
0.91	0.91
Mean value 0.92	0.93
Variance 0.00198	0.00648

We used as a sample the mixture of KCl and NaCl which was prepared by grinding in motar for about 15 minutes and, measured the value $\sigma_E^2+\sigma_M^2$. And then we measured the σ^2 by moving from place to place the sample and got σ_S^2 by Eq. $\sigma^2-(\sigma_E^2-\sigma_M^2)$ (Table 1). Table 1 shows that $\sigma_E^2+\sigma_M^2$ is neglegibly small as compared with σ_S^3.

2) The width of slit and the variance of measured values.

Since the variance of measured values results in the inhomegeneity of samples greatly, the variance of the values becomes more small by using a wide slit and measuring the large area of the surface of samples.

Table 2 shows the significant difference between the measured values that were measured by using the slit of width 2 mm and 5 mm.

3) The measurement method of the diffraction intensity.

In previous experiments both crystallites are so large that the diffraction peaks are very sharp and we used the height of peaks as an intensity.

Table III

I_{KCl}			I_{NaCl}			I_{KCl}/I_{NaCl}	
height	the width of half intensity	area	height	the width of half intensity	area	height	area
7.74	0.60	4.47	8.28	0.47	3.89	0.94	1.15
7.27	0.59	4.29	7.65	0.49	3.75	0.95	1.14
7.63	0.59	4.62	8.15	0.48	3.91	0.96	1.18
8.10	0.58	4.70	8.45	0.49	4.14	0.96	1.13
7.80	0.59	4.60	8.20	0.49	4.02	0.95	1.14
					Mean value	0.95	1.15
					Variance	0.000075	0.00033

This sample is prepared by melting of KCl-NaCl mia.

Table IV

I_{KCl}			I_{NaCl}			I_{KCl}/I_{NaCl}	
height	the width of half intensity	area	height	the width of half intensity	area	height	area
7.87	0.36	2.83	8.07	0.39	3.15	0.97	0.90
7.76	0.36	2.79	7.65	0.39	2.98	1.01	0.94
7.28	0.37	2.69	7.13	0.40	2.85	1.12	0.94
6.69	0.38	2.54	7.01	0.40	2.80	0.96	0.91
7.26	0.36	2.61	7.83	0.39	3.05	0.93	0.86
					Mean value	1.00	0.91
					Variance	0.00055	0.00011

This sample is prepared by rapid evapolation of KCl-NaCl mix. liq.

Table V

I_{KCl}/I_{NaCl}	
hand operation	recording
0.893	0.917
0.887	0.936
0.890	0.928
0.879	0.888
0.881	0.935
0.888	0.905
0.870	0.936
0.884	0.920
0.893	0.896
0.878	0.920
	0.923
Mean value 0.884	0.918
Variance 0.000054	0.00026
F-distribution 4.82	2.97

We studied for specimens of the crystallite of different particle sizes.

That is, we measured the intensity ratio of the sample that after we melt platinum dish the mixture of KCl and NaCl of weight ratio 1, we cooled very rapidly, and the intensity ratio of the sample that we droped into the platinum dish at high temperature (approximatery 600'6) the water solution of KCl and NaCl of weight ratio 1 and we dried very rapidly (Table 3 and 4).

The tables show that there is significant difference between the intensity ratio.

calculated from the height of a diffraction peak and it calculated from the area of the diffraction peak, therefore it gives more accurate results to employ the other than the one.

The comparison between the recording technique and the hand operation technique.

We think that when we measure a diffraction intensity by the automatic recording apparatus, the errors due to the instrument are greater than the hand operation technique.

We measured the diffraction intensity of same surface of KCl and NaCl of weight ratio 1 (Table 5).

Table 5 shows that there is a significant difference between the variances of the measured values by two kinds of technique and the values by hand operation technique are more accurate than the recording technique.

Summary. 1. As may be seen from results of the previous experiment we must take care of the following points to increase the accuracy of the experiment.

1). We must prepare the specimens of very small particle size and grind up sufficiently, for we must prevent the orientation and the inhomogenious mixing of the specimens.

2). Because we must measure a number of particles of a specimen to decrease errors, we should take a large width-slit.

3). We should take the intensity calculated from the area of diffraction peak in principle and we could take the intensity calculated from the height of the diffraction peak, when the effects of the crystallite are neglegibly small.

4). We should measure by hand operation technique.

2, However, it seems that it is so difficult to prepare the homogenious mixture of specimens that we had better take the mean value of several measurements in practice.

3, When we measure the intensity ratio of the mixture KCl and NaCl (weight ratio 1) in the previous conditions, the range containing 95% in values is that of $\pm$ 11% by the relative error approximately. So, if we take the value averaged over five measurements, the relative error is $\pm$ 5% approximately.

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Biological Studies on the Practical Utilities of Poisonous Marine Invertebrates I

—A Preliminary Note on the Toxical Substance detected in the Trumpet Sea-urchin, *Toxopneustes pileolus*—
(With 3 Text-figures)

By
Katsuhiro Okada

(Gakugei Faculty, Tokushima University)

According to the popular information of abalone-fishing divers, the so-called trumpet sea-urchin, *Toxopneustes pileolus*, is a poisonous sea-urchin and it is very dangerous to come into contact with body surface. *Toxopneustes pileolus* is abundant in the rocky bottom a little off the coast of Tokushima Prefecture. Nevertheless, no reports have been found till to-day concerning the biological research for the toxical substance of this species, so far as we have known. From the biological points of view, the writer, therefore, undertakes to investigate some unknown toxins detected in marine invertebrates. Such an investigation may probably contribute to the promotion of utilization of these toxins for the practical applications. In this paper, the résumé will be stated concerning a preliminary study on the detection of poisoning effect upon the oyster heart-beat in the case of supposed toxin derived from *Toxopneustes pileolus*.

On the body surface of *Toxopneustes pileolus*, two kinds of the modified pedicellariae, peculiar to this species, can be found besides the "ordinary" pedicellariae, common in other sea-urchins. For our studies one may be called "trumpet" pedicellariae, and the other "giant" pedicellariae. While alive the body surface of this species is covered by numerous trumpet pedicellariae, each of which spreading out among spines and opening fully its trumpet-like tip with three fine hooks (Fig. 1). Among these numerous trumpet pedicellariae, a few giant pedicellariae of three-forked large tips with similar hooks are found mingled here and there. The white mucous fluid is ejaculated through these hooks, if the fully opened tips of these pedicellariae are stimulated by a sudden and vigorous contact to close themselves vigorously. Such white mucous fluid, secreted from the giant or the trumpet pedicellariae, is supposed to contain the toxical substance of this species or *Toxopneustes*-toxin.

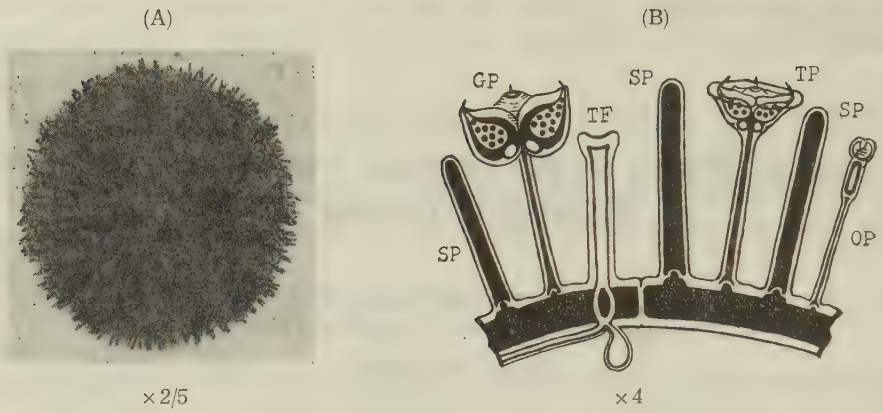

Fig. 1. (A) Photograph, showing specimen of *Toxopneustes pileolus* viewed from dorsal side; and (B) Schematic representation of body wall in section, indicating pedicellaria, tube foot and spine.
GP giant pedicellaria, *OP* ordinary pedicellaria, *SP* spine, *TF* tube foot, *TP* trumpet pedicellaria.

Experiment I. Direct Ejaculation of White Mucous Fluid from Giant Pedicellaria into Oyster Heart No. 1.

A fresh glant pedicellaria is separated from the body surface of sea-urchin by forceps and is kept in contact with the ventricle of oyster heart, prepared in the kymographic apparatus. In case the separated pedicellaria is vigorous and undamaged, three fine hooks of this pedicellaria bite the heart-wall actively, with a positive closing reaction caused by the contact stimulus. Simultaneously, the white mucous fluid is ejaculated from the giant pedicellaria directly into the ventricle of oyster heart. Through this operation, the pulsatory activities of oyster heart are affected with the distinct inhibition, as are seen from Fig. 2, No. 1. Immediately after the operation, the heart gets suddenly shortend with almost abolished pulsation, and then reacts into a clear-cut contraction not to recover again.

Experiment II. Indirect Injection of White Mucous Fluid into Oyster Heart No. 2.

Many trumpet pedicellariae are separated from the body surface of sea-urchin, and they are treated with 0.5 mol KCl solution for several hours. During this treatment, the white mucous fluid is plentifully secreted and deposited from these pedicellariae, probably due to some stimulation given by KCl ion there. The deposited mucous fluid is pipetted quickly and bathed in the normal sea-water repeatedly. In such a manner, the mucous fluid can be collected indirectly from these treated pedicellariae and used for the injection into the oyster heart by means of a minute syringe. In course of experimental operation, the pulsatory activities of oyster heart are also subjected to the similar inhibition to that of Experiment I, as are seen in Fig. 2, No. 2. As soon as the mucous fluid is injected into the ventricle, the heart presents a rapidly increased tonus. About

several minutes later, the tonus reaches the maximum, soon abolishing its pulsation completely.

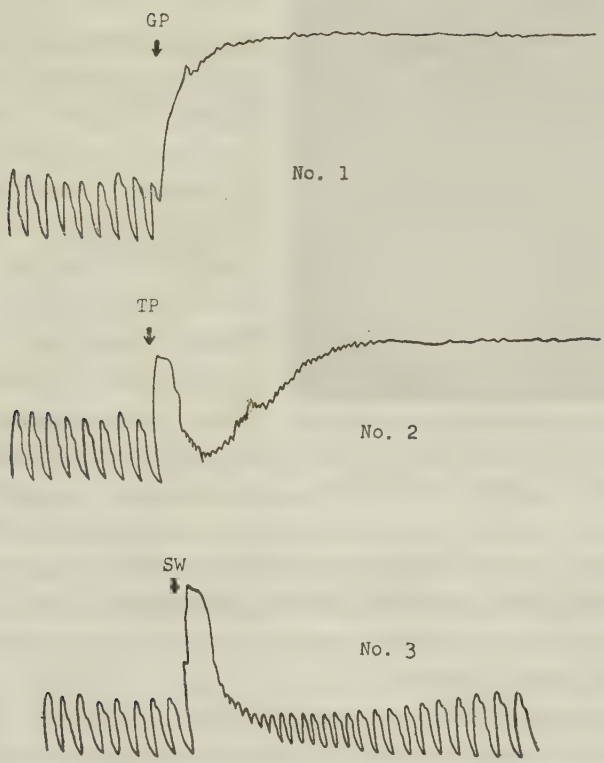

Fig. 2. Copy of kimographic records of pulsatory curves of oyster hearts, showing inhibitory effects caused by experimental and control operations at 28°C.
No. 1. Pulsation of oyster heart No. 1 in Experiment I.
GP Mark in contact with giant pedicellaria.
No. 2. Pulsation of oyster heart No. 2 in Experiment II.
TP Mark at injection of white mucous fluid collected from trumpet pedicellariae.
No. 3. Pulsation of oyster heart No. 3 in Control Experiment.
SW Mark at injection of sea-water.

Control Experiment. Injection of Sea-water into Oyster Heart No. 3.

In the experimental operations stated above, the pulsation of oyster hearts may has been subjected to the inhibitory effect of the mechanical stimulus caused by the hooks of giant pedicellaria or the needles of syringe, in addition to the chemical stimulus of white mucous fluid under investigation. The inhibitory effect of mechanical stimulus following the experimental operations is here open to question. As a control experiment to clarify this question, normal sea-water is injected into the ventricle of oyster heart by use of the same syringe. At this control operation, the oyster heart reacts instantly into an abnormally increased contraction, because of the mechanical stimulation of injection, as are seen in Fig. 2, No. 3. The pulsation of oyster heart, however, is seen speedily recovering

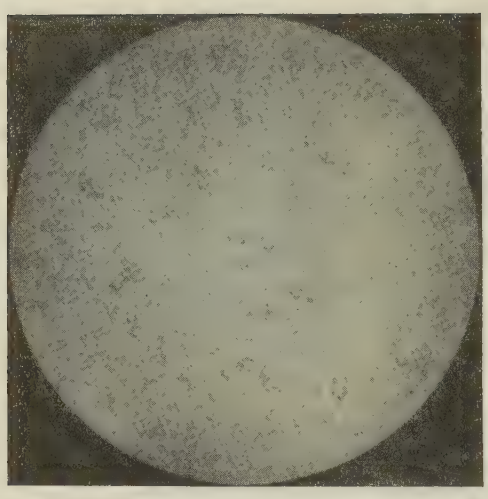

Fig. 3. Microphotograph, showing "poison-corpuscles" of white mucous fluid, derived from trumpet pedicellariae. X400.

the original rythm within several mintes. As the result of this operation, it is found that the mechanical stimulus just investigated gives only an instantly increased contraction to the palsation of oyster heart. Accordingly, the distinct inhibition to the pulsatory activities of oyster hearts, mentioned in Experiments I and II, can safely be presumed to be due to an unknown toxical substance contained in the white mucous fluid.

Through the microscopic observation of white mucous fluid collected from trumpet pedicellariae, we can find a numerous "corpuscle" of particularily fine dumbbell shape (Fig. 3) and the surrounding viscous "matrix" of milky colour. These components of the mucous fluid, the poison-corpuscles and the poison-matrix, are insoluble to sea-water, alcohol, acetone of ether, while they are perfectly soluble in the heated 0.1 N HCl when heated condition.

On the other hand, they are separated into two different fractions by high centrifugal force. One is the centrifugal or corpuscle fraction and the other the centripetal or matrix fraction. Each fraction can thus be independently injected into the oyster heart. The respective effect of the poison-corpuscles and of the poison-matrix upon the oyster heart can be also investigated experimentally. It is a matter of wonder that the inhibitory effect of poison-corpuscles is quite different from that of poison-matrix. It is suggested that some remarkable correlation, like synergism or antagonism, may exist between the two poisoning effects. In order to clarify this point, research will be continued further from both physiological and biochemical points of view. In conclusion, it has been confirmed through the present experiments that a remarkable poisoning effect upon the oyster heart is detected in the white mucous fluid secreted from both giant and trumpet pedicellariae of *Toxopneustes pileolus*.

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Sedimentological Examination on the Influences of Oceanographic Environments upon Marine Humus Distribution

By
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I. INTRODUCTION

Organic substances, so-called MARINE HUMUS (Waksman, 1933), in marine sediments are fairly varied in chemical composition according to different environments of sedimentation. Organic matters in sediments, because of their greater susceptibility to change with varying conditions of deposition, might prove to be more sensitive indexes to the environmental conditions than the inorganic ones do. So, it will be desirable to examine how the properties of the water column overlying the site of deposition influence upon the regional distribution of organic materials in the sediments. It seems, however, difficult to indicate the degree of the dynamical complexity all the year round concerning oceanographic conditions in a given area. While the mass properties of sediments are induced by the variation of environments of the water column and suggest the integral contribution of the oceanographic conditions to subaquatic accumulation.

In the present paper, the regional distribution of marine humus in the southeastern sea of Hokkaido has been discussed with reference to the results obtained from serial oceanographic observations (Koto, 1952) and also to the mass properties of the bottom samples as determined by chemical analysis. Moreover the area under discussion seems most suitable for the investigation of the influences of oceanographic environments on humus distribution, because there the submarine topography (Ogaki et al. 1953) appears rather even and there is no large river supplying a good amount of terregenous debris. The oceangraphic condition then, appears to be the most important factor controlling organic accumulation on bottom floor.

Oceanographic condition of this area may be summarized as follows: The open sea is usually under the influence of Tsushima Current, but the movements of the water off Oshima Peninsula seem to be complicated because of the geographic configuration on the coast. The area off the coast of Hidaka is usually under the influence of Oyashio Current, especially in autumn and winter. Off the mouth of Funka Bay, a part of the upper water of the Oyashio is usually isolated hydrographically by the water of the Tsushima rising during spring and summer.

The isolated mass of water moves as a counter current against the Tsushima. (Fig. 3; Koto, 1952)

Seventy nine bottom samples were taken and dried at 100–105°C, and submitted to chemical or mechanical analysis. The carbon content was determined by the use of Tiurin's modefication of Schollenberger's method and the nitrogen one by the usual Kjeldahl method. The loss due to ignition of the samples was also determined by using the common procedure.

Mass property of the samples was investigated through mechanical analysis. From the data taken from the mechanical analysis a cumulative frequency curve was prepared for each sample on logarithmic probability paper and the median diameter, and the first and third quartile measures were obtained from the curve. From these measures, Trask's (1932) coefficients of sorting and skewness were computed. The sorting coefficient is determined as $S_0=\frac{Q_1}{Q_3}$, and the skewness coefficient as $S_k=\frac{Q_1 Q_3}{Md^2}$, where Q_1 and Q_3 $(Q_1>Q_3)$ are the quartile measures while Md indicates the geometric median diameter.

II. SEDIMENTOLOGICAL INSPECTION ON MARINE HUMUS DISTRIBUTION

The regional distribution of organic materirls in sediments are illustrated in Figs. 4–6. These maps on humus distribution appear to indicate something about correlation between the organic accumulation in sediment and the environmental conditions in the site of deposit.

The bottom samples were classified into several types based on the shapes of the cumulative frequency curve on grain size. With reference to the sediment type and oceanographic character, the area under the discussion was divided into several regions as illustrated in Fig. 7. Figure 8 shows graphs of sediment types on the respective regions.

1). A–Region:

The region is a hemipelagic part of the area investigated, the water depth ranging from 500 to 840 meters. In the region, the influence of Tsugaru Current, a branch of the Tsushima, is predominant.

Most of the sediments has a fairly fine median diameter, 0.010–0.045 mm and has been poorly sorted (S_0 averaged, 12.3). The sedimentation going on in this region appears remarkable in deposition process rather than in erosion or transportation one. A relatively poor sorting in A_2-region may account for the presence of kind of rip current.

Sedimentary accumulation of organic matter seems fairly abundant in this region: The average content of organic carbon in the sediment ranges from 1.21% to 1.66% and that of nitrogen totals from 0.143% to 0.182%. Decomposi-

tion equiiibrium of organic materiais in the sediment appears to be fairiy progressive, for the ratio, C/N, gave an average near 8.6.

2). B-Region:

The major part of the region is the shelf east of Oshima Peninsuia. The movement of water is much compilcated because of the geographicai configuration. The sedimentological characters of the region are as follows: The median diameter of sediment is mostly of either coarse or medium sand, 0.26-0.88 mm. The sediment has been fairly well sorted (S_0, 2-3), and especially those in B_1-region best sorted. Of the sediments in B-region, however, a finer fraction should have been somewhat poorly sorted; this tendency will be more remarkable in B_2-or B_3-region. On the other hand the sediments in the vicinity (B_4) of St. 16 have been extremely poorly sorted, as 32.7 in S_0. Such a poor sorting is significant in particular of their finer fraction (Sk=0.03). These characteristic coefficients observed on B_4-region should be attributed to a peculiar deposition due to a small eddy widely seen near the coast.

Of the B-region, organic accumulation in the bottom does not appear so much abundant: The sediments have either organic carbon contents from 0.3% to 0.8%, or nitrogen contents from 0.04% to 0.12%. Comparatively small values, 5-7, in the C/N will be common in the region although somewhat different values are observed in B_1-region. These facts might show that there would be found not only poor accumulation of terregenous organic matter due to better sorting but also remarked complexity of oceanographic environments.

3). C-Region:

The continental sheif off the northeastern coast covers this region. This region can be divided into two parts according to sediment type and oceanographic condition. One of the two is the area involving C_1 and C_2: Here most of the sediments is of clay or silt and has been poorly sorted, as $Md<0.01$ mm and $S>9$. In this respect a kind of eddy or a counter current usually seen above area will be taken into account.

Although the sediment type on the C_1-region is almost analogous to that on A_1-or D-region, the organic accumulation is not so much abundant as that in these analogous regions.

Another part of the C-region is composed of the respective regions of C_{3-1}. The sediments in the above part have been well sorted and indicate the sorting coefficient ranging 1.4-4.6 or mostly near 2, but their finer fractions have been rather poorly sorted than the coarser ones.

Of the C_4-region, or the major portion of the C-region, the sediments have 0.06-0.15 mm median diameter and have been well sorted (S_0, 1.4-2.4), and showing some symmetrical grain-size distribution. Thus the organic materials in the sedi-

ment will be not only less abundant in quantity but also rather terrestrial in quality.

The character of the sediments in C_3-region seems somewhat peculiar, that is, their median diameters are near 0.05 mm and the sorting of them appears relatively poorly done, 2.8-4.6 in S_0, as compared with the other subregions. The above sediment type on C_3-region may look almost similar to that on A_3-region. Here, some rip currents might be usually observed in C_3-region and a fairly good amount of organic matter will naturally be accumulated on the bottom floor.

4). D-Region:

D-region covers the northeastern part of the area under review. The oceanographic environment appears to be a great deal characteristic: Most of this region is usually under the influence of the isolated portion of the Oyashio, as mentioned in the introduction, during spring and summer. Hence the type of the sediment should be somewhat strange.

The sorting of sediments in the region appears to be not only extremely poor but much varied. The cumulative curves shown in Fig. 8-4 might suggest some influence of mass movement of unconsolidated sediment caused by mud flows. These transportation effects would be more significant in the *E*-region (stations of 42,65 and 76) judging from the abnormal shape of the cumulative curve.

The sediment in D_1-region, it may be remarked, shows a characteristic mass property: The sediment type which indicates median size near 0.015 mm or sorting coefficient near 7 appears to be more or less analogous to that of the pelagic area as *A*-region, notwithstanding the grain-size distribution is skew towards the coarser size as contrasted with the case of the *A*. This fact may show that a peculiar sedimentation process is usually going on in this subregion. Such process might suggest that the D_1-region is located at the center of the circular counter current against the Tsugaru Current. Sedimentary accumulation of organic matters in the subregion, has consequently, has been fairly abundant (1.0-1.4% *C* and 0.13-0.21% *N*) as compared with that in the other subregion. Neighbored the D_1-region, D_6-region involves some characteristic stations as 49 and 52, where a comparatively high ratio of *C* to *N* was observed of the sediments. This fact might account for the complexity of water diffusion as well as the transportation of unconsolidated sediment.

III. RELATIONS OF SEDIMENTOLOGICAL COEFFICIENTS TO ORGANIC ACCUMULATION IN THE SEDIMENTS

The sedimentological indexes, as median diameter or coefficients of sorting and skewness, of the bottom sample were examined in order see if they would indicate any relationship to quality or quantity of organic materials contained

in the sediment. A series of graphs in Fig. 9 shows these relations.

Although organic accumulation appears rather correlative to median size (Fig. 9-1), it will be hard in general to see any definite correlationship to the coefficients of sorting and skewness. Further close observation in detail will lead to more concrete solution of the question concerning the relation of these coefficients to organic accumulation.

Plots of the organic content against the sorting (Fig. 9-2, 3) for the relatively well-sorted sediments, as indicated in S_0 below 5, fall in some reasonable mass, while those on the poor-sorted sediments seem almost at random. With the progress of sorting, the well-sorted sediments appear to reduce their organic contents, and the redution will be remarkable in the case of nitrogen content. On the other hand, plots regarding the poorly sorted sediments will show little definite relationship because of their random deviations. However, the abundance of carbon content will decrease with the reduction of the degree of sorting while that of nitrogen content will be rather increasing with reduced sorting, until a more or less definite ratio of carbon to nitrogen would be attained. Further it is noticeable that the constancy of carbon nitrogen ratio appears rather less reliable in the well-sorted sediments than in the poorly sorted ones : The progressive sorting will lead to settling of larger terregenous debris as well as to removal of colloidally organic detritus.

As regards the well-sorted sediments which were observed in B-or C-region, the plots of organic content against the skewness shown in Fig. 9-5, 6 indicate that a considerable deviation of skewness appears not so much influential upon the organic accumulation. This fact will also show that the organic materials accumulated in the well-sorted sediment will be contributed effectively by large organic debris or remains rather than by finer detrial materials. The quantity of organic matter contained in the well-sorted sediment decreases with approach of the skewness to unity.

Plots on the poorly sorted sediments, as in A_1 or D-region, are dispersed on the diagram, that is so say, there will be little possibility to see any relationship between the organic content and the skewness.

SUMMARY

(1) Marine humus distribution in the southeastern sea of Hokkaido has been examined in relation to the oceanographic conditions, through the agency of sedimentological indexes, as median diameter and Trask,s coefficients of sorting and skewness, of the bottom samples.

(2) The bottom samples have been classified into several groups on the basis of the shape of cumulative curve on grain size. Here, the area was divided into several regions with reference to the sediment type as well as to the oceanographic environment. Such partition of the area would be serviceable for clarifying

some correlation of organic accumulation to dynamical sedimentary process going on in the side of sedimentation.

(3) The organic accumulation has been discussed in relation to these indexes. Organic accumulation might have rather negative correlation to the median size. Although it would be hard in general to see any definite correlationship to these Trask's coefficients, further studies of these relations reveals that not only quantity but quality of the sediment would be more or less influenced according to the degree of sorting which had been going on in the corresponding location.

The author is much indebted to Prof. H. Tominaga of Tohoku University for his untiring encouragement during this investigation. To Prof. N. Suzuki of Hokkaido, great acknowledgement is due for giving facilities for the work. Further the author wishes to express his thanks to Mr. K. Ohgaki, Master of Hokkaido Regional Fisheries Research Institute, for the facilities he gave me for collecting bottom samples in this area.

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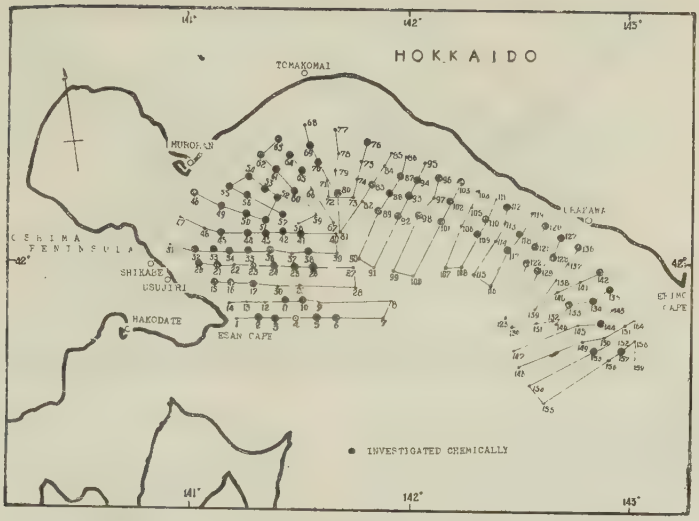


Fig. 1 Chart of Stations Observed (Sept. 3–21, 1952)

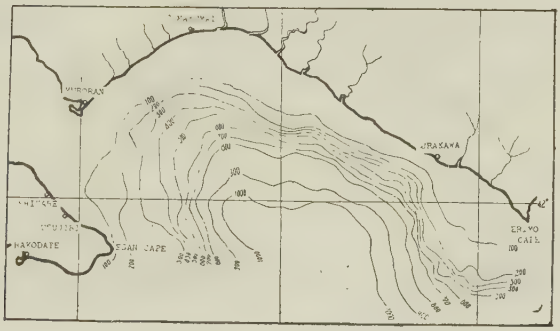


Fig. 2 Submarine Topography.

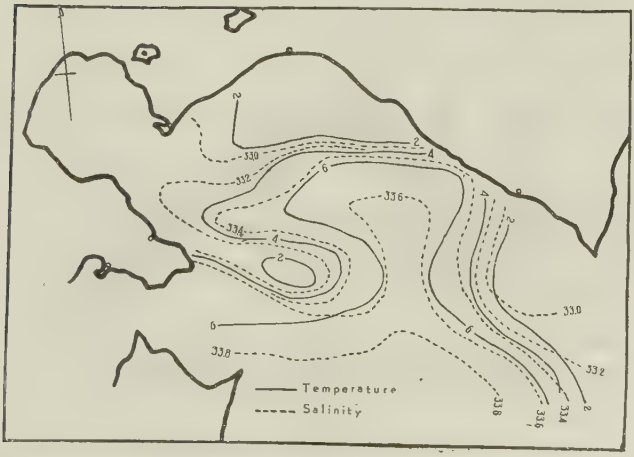


Fig. 3 Oceanographic Chart (50 m Layer; May 4–12, 1950: Koto, 1952)

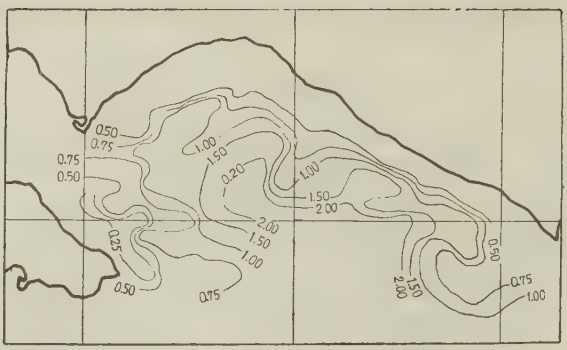


Fig. 4 Distribution of Organic Carbon Content in Sediment

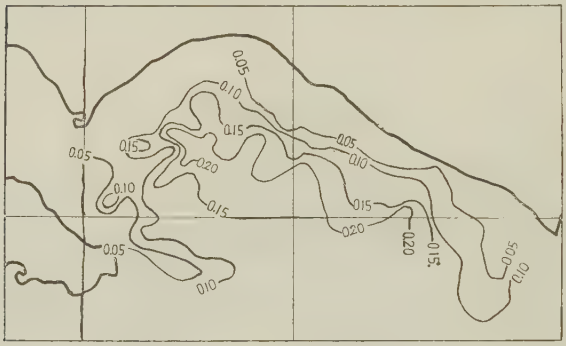


Fig. 5 Distribution of Total Nitrogen Content in Sediment

Fig. 6 Distribution of C/N in Sediment

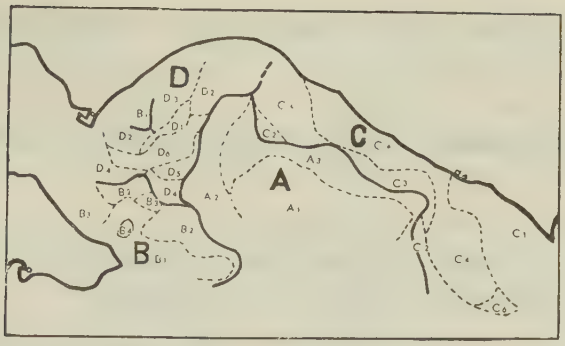
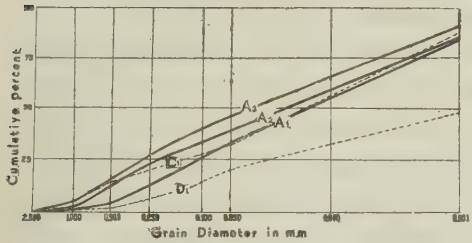
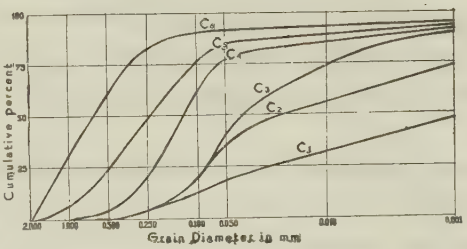


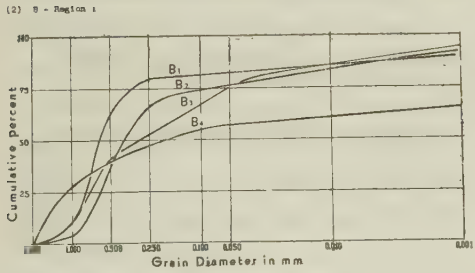
Fig. 7 Sedimentological Portion of the Area Investigated



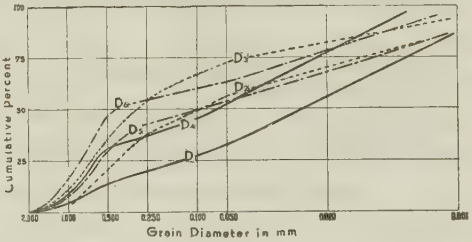
(1) A-Region :
A_1 : 89, A_2 : 4, A_3 : 80 : C_1 : 159, D_1 : 67



(3) C-Region :
C_1 : 159, C_2 : 129, C_3 : 118, C_4 : 144, C_5 : 94, C_6 : 157

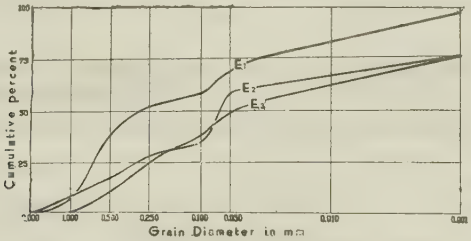


(2) B-Region :
B_1 : 4, B_2 : 10, B_3 : 35, B_4 : 16



(4) D-Region :
D : 64, D : 69, D : 62, D : 48, D : 51, D : 50

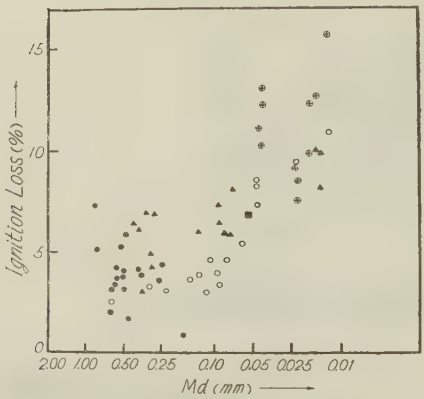
Fig. 8 Graphs of Cumulative curves Showing Sediment Types



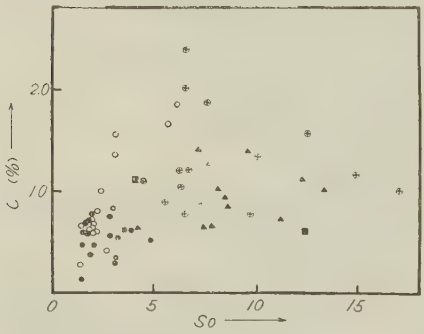
(5) E-Region ,
E : 65, E : 76, E : 42

Fig. 8 Continued

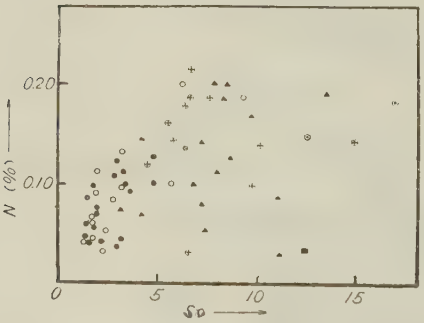
Fig. 9 Relations of Sedimentological Indexes to Organic Content in the Sediment



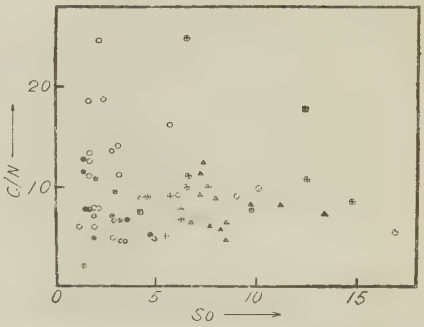
(1) Median Diameter and Ignition Loss



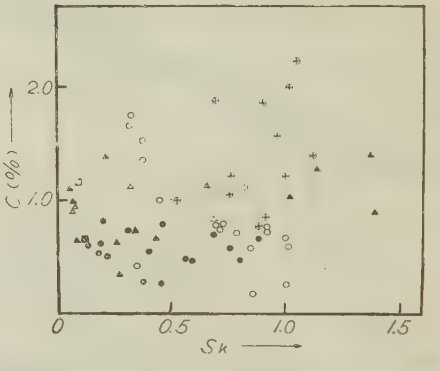
(2) Sorting Coefficient and Organic Carbon Content



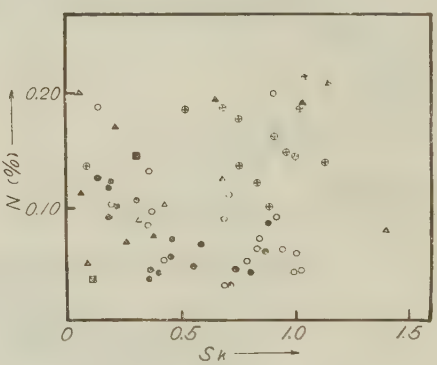
(3) Sorting Coefficient and Total Nitrogen Content



(4) Sorting Coefficient and C/N



(5) Skewness Coefficient and Organic Carbon Content



(6) Skewness Coefficient and Total Nitrogen Content

⊕ A—Region
● B—Region
○ C—Region
▲ D—Region
■ E—Region

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October 1955

On the Exploration of the Naruto Straits

By
Takeo Goda and Mamoru Kuroiwa.
(Gakugei Faculty, Tokushima University)

INTRODUCTION

The Naruto Straits is situated in the eastern part of the Seto Inland Sea, joining the Harima Sea and the Kii Channel. Though it has a width of 1,300 meters, its navigable passage is limited to only 300 meters wide because of its very reefy or rocky sea-bed.

There is 5 hour time lag between the establishment of the Harima Sea and that of the Kii Channel and when the former is at high water, the latter is at low water. Thus the water turns reciprocally and yet the stand of tides never exceeds 10 minutes. This causes a great difference in the sea-level of the Straits reaching 1.4 meters at the maximum and results in the famous swirling torrent of Naruto whose velocity sometimes reaches 10 knots per hour. There is a large rock-head about 2 meters high above the sea-surface, which is called "Naka-se," and its neighbourhood is full of sunken reefs. Between "Naka-se" and "Tosaki," the east end of the Straits, there is a passage navigable only by small fishing crafts. The western parts of the Straits abutting on a steep rocky and reefy end of 100 meters depth, offers a good fishing ground to the fishermen using hand lines, but the rapid current makes the fishing rather difficult.

Schools of fish on their way to the Harima Sea pass mainly through this Straits and therefore it is very interesting to study the relations between the Straits, current and fishery. Nevertheless, the Straits was a fortified zone until the end of World War II and studies of this kind were not attempted.

Here, an exploration has been carried out with this purpose in view and the results are given in the following report.

PLANS AND PREPARATIONS

The present plans are chiefly related to the investigation on the conditions of the sea-bed of the Straits.

(1) Formation of Diagram.

Six observation lines, parallel and 100 meters apart between the range of 1 kilometer both north and south from its center, the narrowest part of the Straits, are ertablished as shown in Fig. 1. The necessary observation points, 106 in all,

are fixed on these lines in accordance with the cross bearing method, numbered in turn according to the order to be observed.

The ship's heads of these observation lines are set for N 14°W and S 14°E (magnetic course), viz. N 14°W corresponding with the top of Mt Yashima and S 14°E that of Mt. Ishima respectively. The mountain tops are of use when distant view is possible and the compass when it is not.

The chart No. 112 published by the Maritime Safety Agent of Japan was used.

(2) Observation Boat

The "Tokushima-maru" (gross tonnage 32, draft about 1.5 meters) belonging to the Tokushima Fishery Experimental Station was employed. The sounding was undertaken by the fish-finder fixed to the boat about 1 meter below the water surface. The speed of the boat was maintained at 6 knots per hour throughout the observation.

(3) Fish-finder

The fish-finder has sounding capacity of 200 meters in the depth recording with the dry method.

(4) Other Instruments

2 sextant, 2 stopwatches, one time bell and etc.

(5) Time of Observation

Observation was made just before and after the stand of tides when the sea was calm and distant views were available.

(6) Method of Observation.

By means of the time bell, all members of the team observed simultaneously.

(7) The others

Throughout the observations, the speed of the boat and the time were recorded by the hand log.

RESULTS OF OBSERVATION

The first exploration was carried out on March 10 and 12, 1953. Both these days, the weather and the conditions of sea-surface were quite favourable, but on the 10th, sea fog prevented distant views.

On account of the rapid current of the Straits, it happened sometimes that the observation could not be made well at some observation points as arranged and so the results of such observations were omitted as unreliable data as mentioned below :

(1) When the observation was interfered by the rapid current and the short intervals of neighbouring observation points,

(2) When the position of the observation boat was doubtful.

The observed data are summarized in Fig. 3, 4, 5, 6, 7 and 8, where curves

indicate the depths of sea-bed along the observation lines as numbered in Fig. 2, the upper horizontal lines showing the sea-levels. Among the vertical lines in these figures, some are with numbers and others without. The numbers of the former correspond with those in Fig. 2, i. e. those of the numbered observation points respectively and the latter indicate that their observations are not quite reliable.

The measurement of depth by the fish-finder accompanies some errors caused by the temperature, the content of salts and the pressure of the sea water, but these are negligible when compared with those caused by the irregularity of the sea-bed. As mentioned above, it is necessary to make a slope-correction (as it is considered that there are steep slopes having 70 to 80 degrees) for the accurate observation.

From these figures, the following points were considered. (1) The dike stretches from "Nakase" rock-head to south-east of "Tobishima" islet and falls off gradually. Irregular-crested white horses presumably caused by the upwelling, the changed low-current dashing against the dike, appear on the ebb at the east of "Tobishima." This fact proves this point of view. The sea-bed, as the diagrams show, consists of steep rocky slopes.

(3) The fish-finder recorded the deepest spot 1 kilometer north of the Straits. This corresponds to the chart indicating the depth of 217 meters.

(4) As is sekn in the diagrams, several schools of fish guessed to be sardine (Sardina-melanostica) were noticed near the surface during the observations.

CONCLUSION

As stated above, the present observations at 31 points are not enough to conclude the state of the sea bed of the Naruto Straits, but a rough figure with it is considered to have been obtained.

Further detailed observations regarding further points are planned to reveal the whole aspect of state of the Straits.

The author wishes to express his sincere appreciation to Dr. M. Ishibashi for his valuable suggestions given to this research.

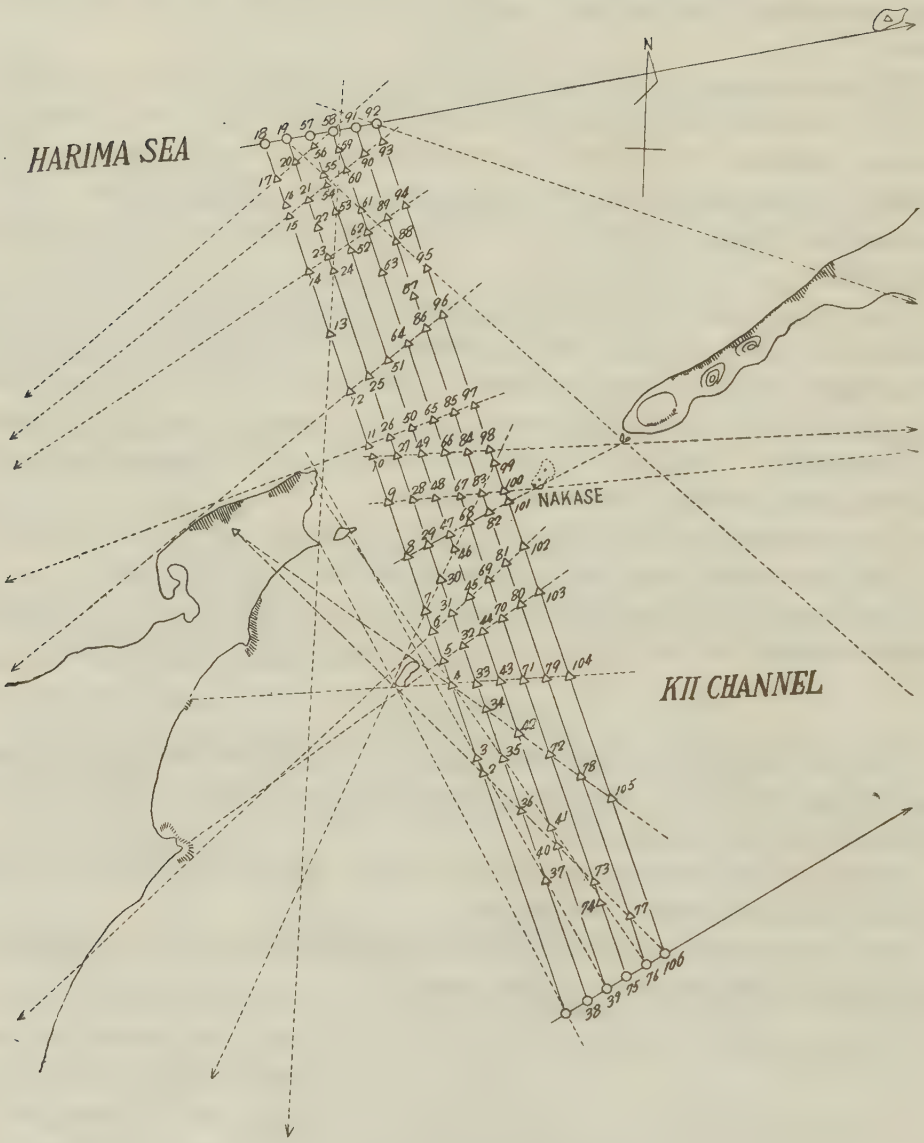

Fig. 1 Plan of Observation Point

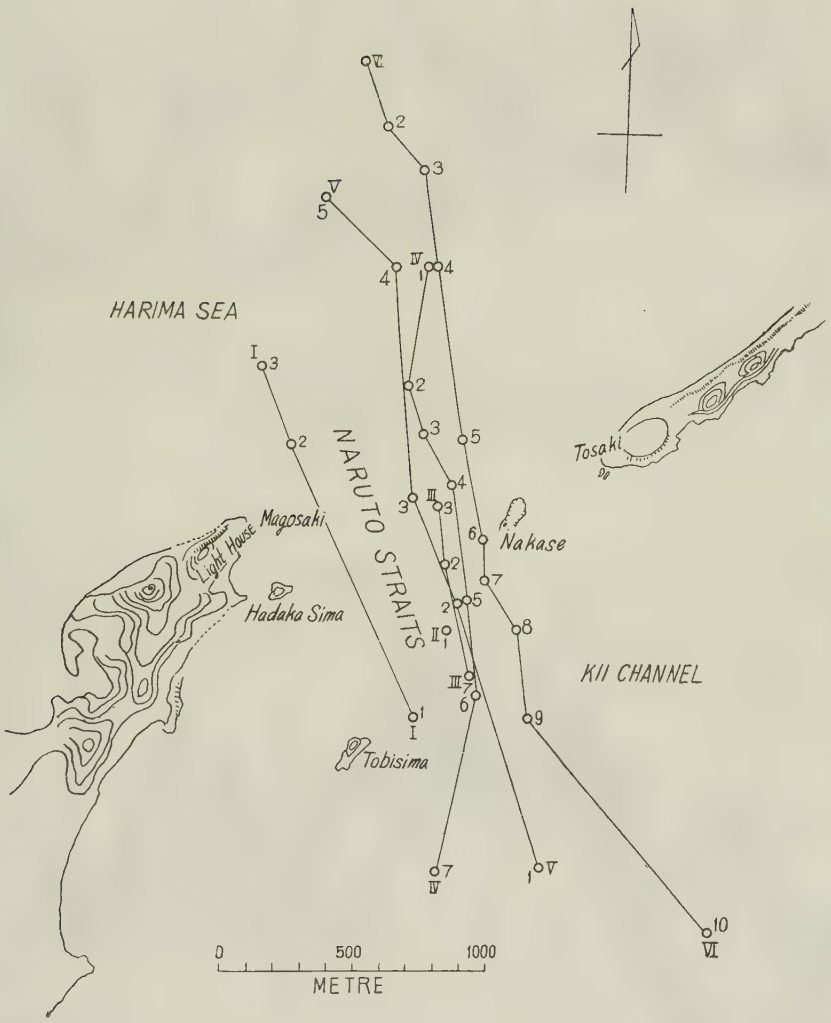

Fig. 2 Observation Points

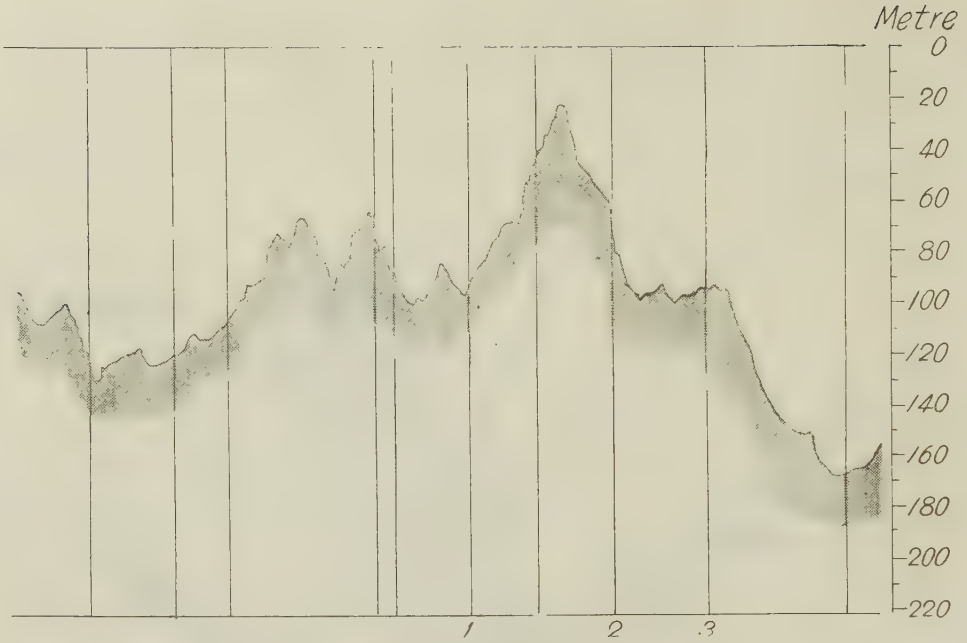

Fig. 3 Diagram of Observation Line I

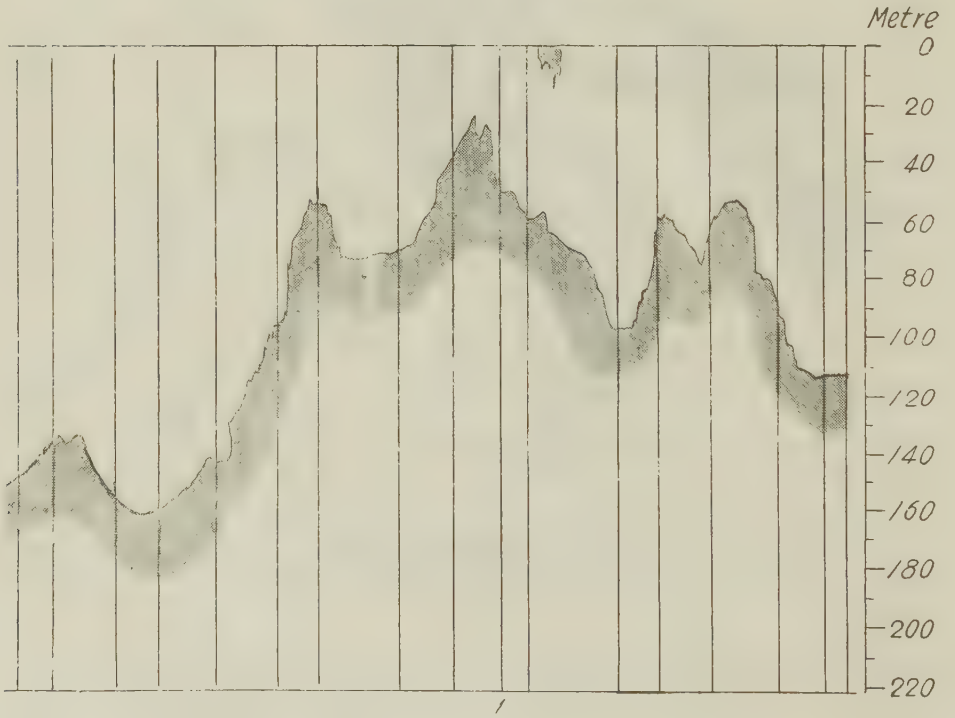

Fig. 4 Diagram of Observation Line II

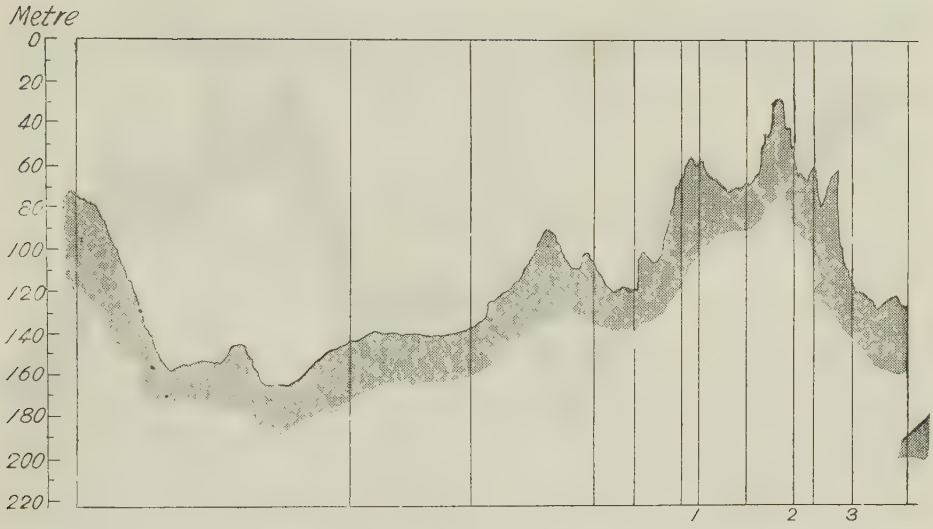

Fig. 5 Diagram of Observation Line III

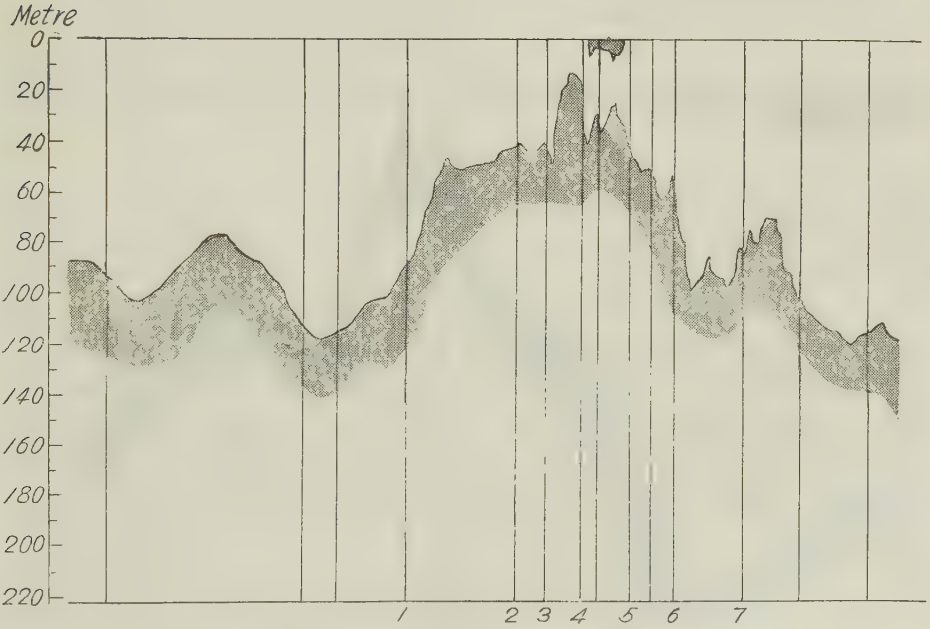

Fig. 6 Diagram of Observation Line IV

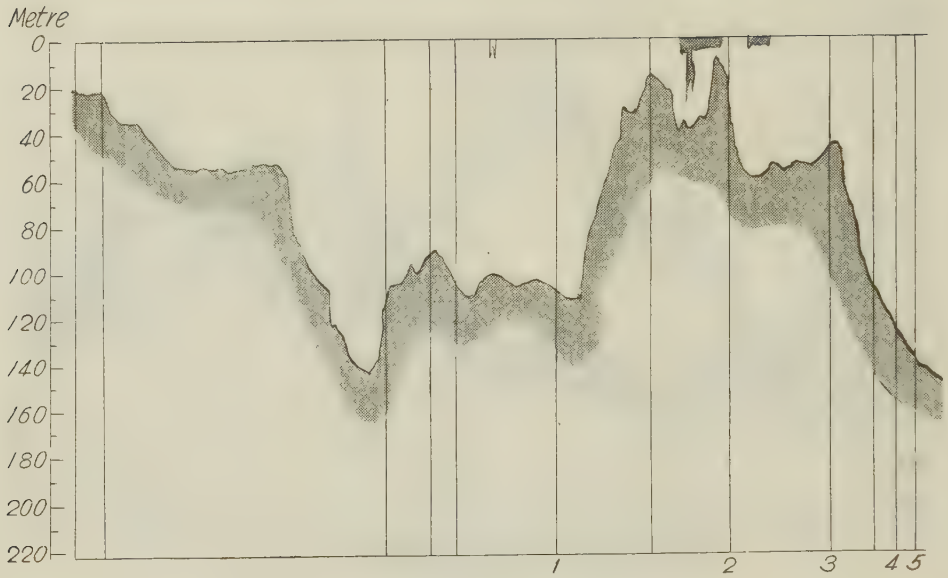

Fig. 7 Diagram of Observation Line V

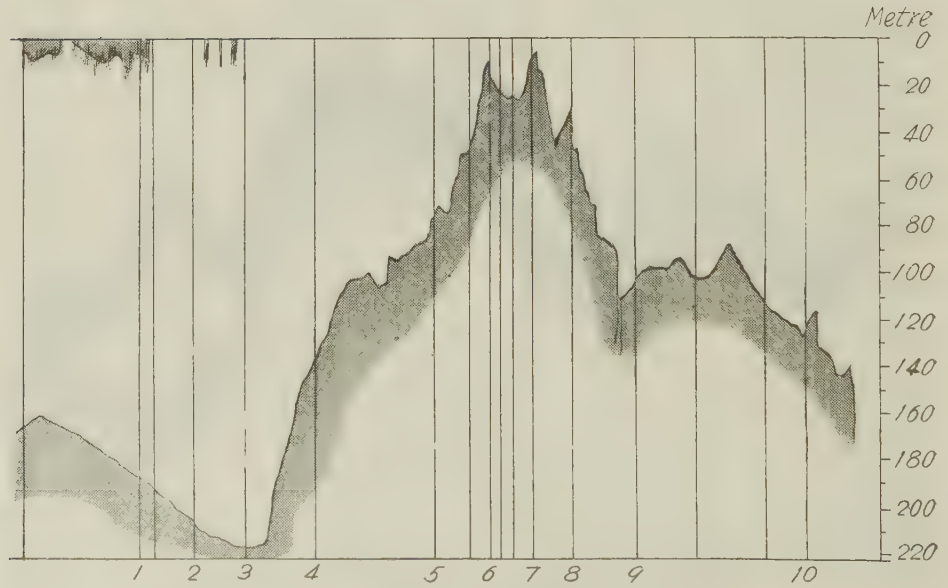

Fig. 8 Diagram of Observation Line VI

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Preliminary Note on the Bottom Topography of the "Damo" Area.

By
Kaoru Tatara

(Inland Sea Regional Fisheries Research Laboratory, Japan)

PREFACE

Iyo-nada, the western part of Seto Inland Sea, has been known as the wintering water for the important bottom fishes in Inland Sea. Since the spring season of 1951, the southern part has been especially noted as a new fishering site for red sea bream. Fishermen have got a rough idea of the bottom topography through their fishing experiences; and called this area "Damo" or "Dama".

The depth there ranges 60 to 100 meters by chart, while our observation shows that it varies so much around the area.

The usual roughness of bottom topography was first observed, on an echo record taken by Mr. Nitta in September, 1953, when he passed through this area on board Naikai-maru, the research vessel of Inland Sea Regional Fisheries Research Laboratory. Further in February, 1954, the vessel covered the area again to look into the bottom topography there more closely.

Some features observed in these surveys will be described briefly in this report.

SURVEY AND RESULT

More than 100 square miles, including the "Damo" area, was covered, as shown in Fig. 1. The echo-sounder of the shallow-water type was used. It has three ranges of depth, that is, 0–40, 40–80, and 80–120 meters.

Some of the records are shown in Fig. 2., where horizontal unit distances are indicated by dots. This survey was done in an area of about 347 meters. In some instances when the recorder does not work normally the unit distance is not equally represented in length on the records.

Along the line A–B, the bottom appears flat, slightly sloping southward by 1 meter/2.1 Km.

Along the B–C line, it starts just as well but the echo draws a slightly rough curve where it crosses the 70-meters bathymetric line. And then it disappears near the station C, but the condition is not the same as before.

Along the C–D line, the bottom condition is rather rough but not sharp. At the station D, the wire sounded 85 meters and the echo 83 meters, while the chart

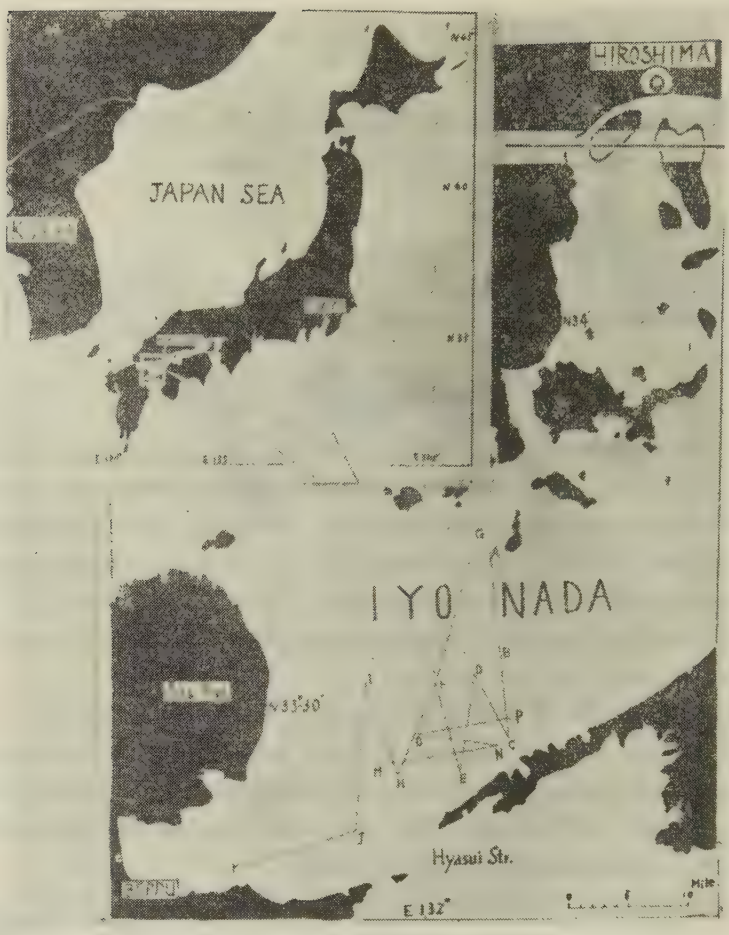

Fig. 1 Iyo-nada and approarches

shows 67 meters in depth in Fig 3. The difference seems too large.

Along the D–E line, the bottom shows alternate ups and downs around 80–85 meters deep, and then suddenly gets shallow about 1 mile, but afterward the roughness begins to be conspicuous again. The record between D–D′ shows this most rigged feature in this area. And it ends rather flat at the station E.

Along the E–F line, the bottom feature varies reversely to the line D–E. It does along the F–G line as well reversely to the line A–B–C. Along the F–H line, extending southwestward from F station, the bottom goes up and down alternately about 50–70 meters deep, and ends rather smooth at the station H.

Along the I–J–K lines, there are small ups and downs near the station J.

Along the eastward or westward lines, on the other hand, the general feature is different. Everywhere along the N–O line, crossing the most rigged region of the "Damo", are seen ups and downs, some of which reach about 40 meters in height. The roughness along the line O–O′ is very conspicuous and there appears to be the center of the "Damo" area around there. While the station P may

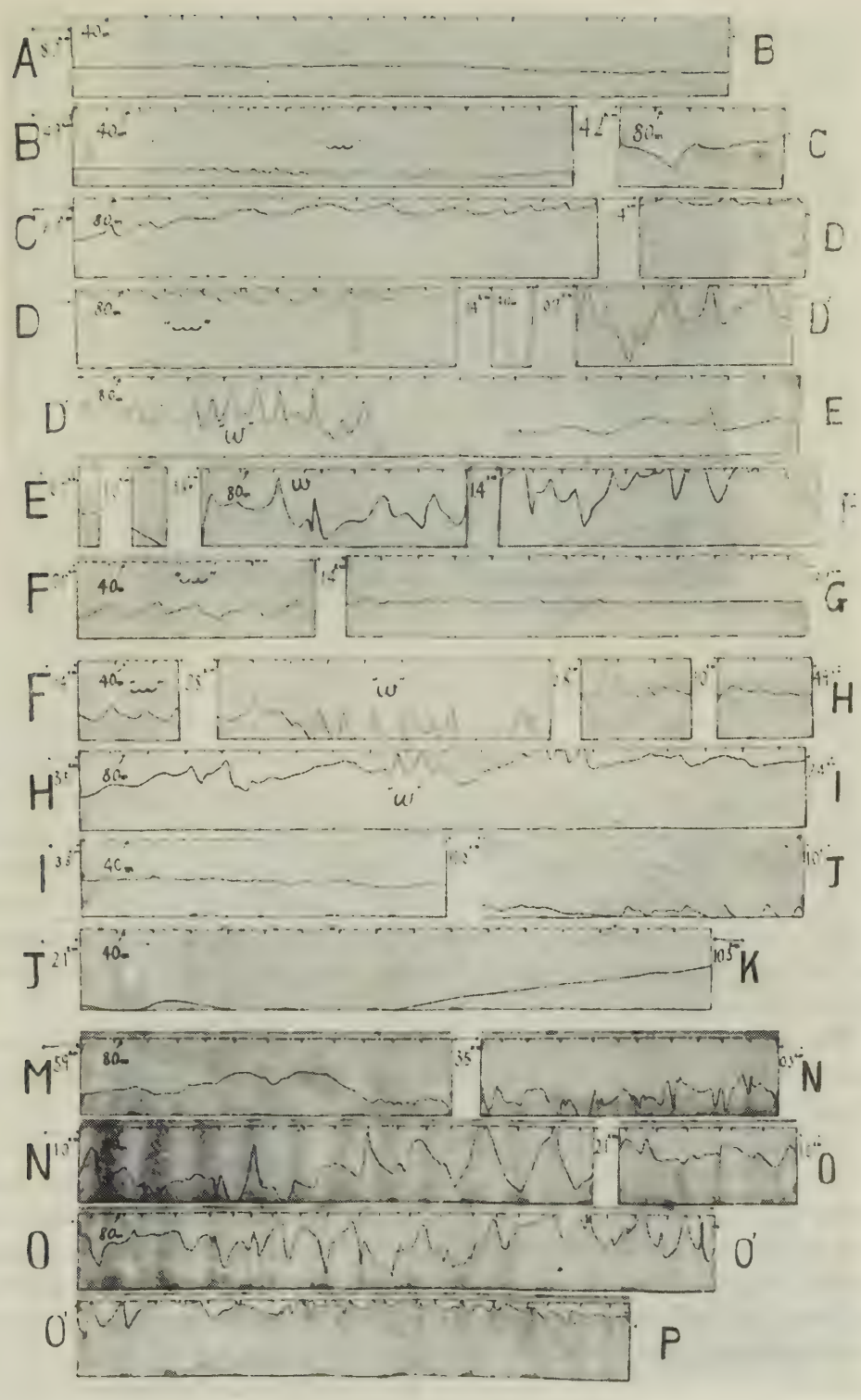

Fig. 2 Echo-record of each line

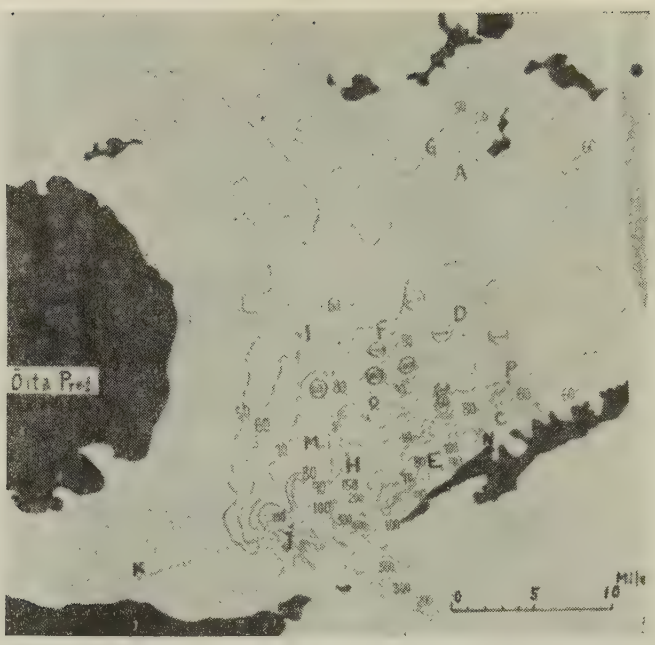

Fig. 3 Bathymetric chart (I)

be located outside center.

DISCUSSION

It should be noted that the difference between the depth expected from the bathymetric chart, Fig. 3, and that of echo-paper is about 20 meters at station D. The mean sea level is about 1.8 meter high than nearly the lowest low water, and the tidal rise of sea level around this area is supposed to be 2 to 3 meters at most. At the stations where the bottom is so flat as is along the line A–B and F–G, no significant difference between two soundings can be found, considering the tidal rise of sea level.

Not only along the A–B and F–G lines but also the H–I and I–J lines, these figures seem to be equal in both, while they often show discrepancies on the "Damo" area, especially around its central part.

The rough part of D'E line being named "w" type, similar patterns are observed on the marked part of F–H line, and partly along the E–F and H–I line. Waving patterns, maked "…", observed along the DD' line, are seen midway along the B–C line and near the station F along F–G and F–H lines respectively. Not only these marked parts are similar in shape but their locations along the lines show that they are interrelated. The "w" patterns are seen where the 80 meters bathymetric line spreads into the shallower area in Fig. 3; and the "…" patterns are seen around the transition area between the flat bottom and the "Damo".

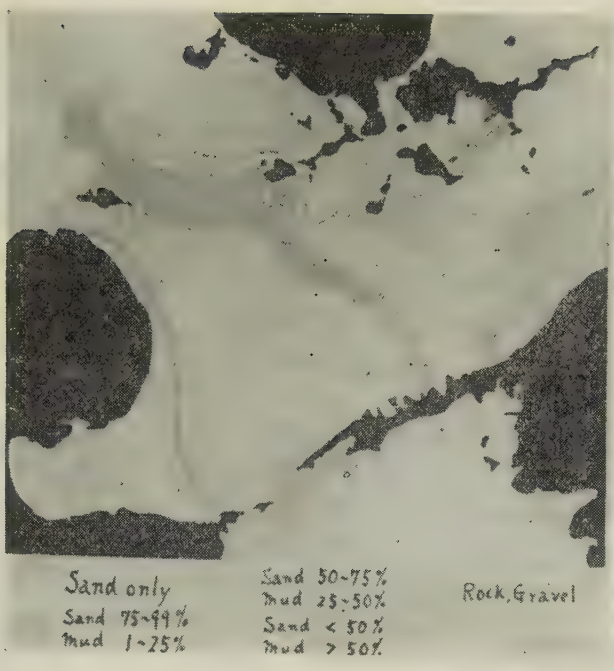

Fig. 4 Bottom Sediments

Bottom sediments of the "Damo" area are sands and gravels, as illustrated in Fig. 4. From this the landscape of the central "Damo" area seems to consists of hill after hill made of sands and gravels.

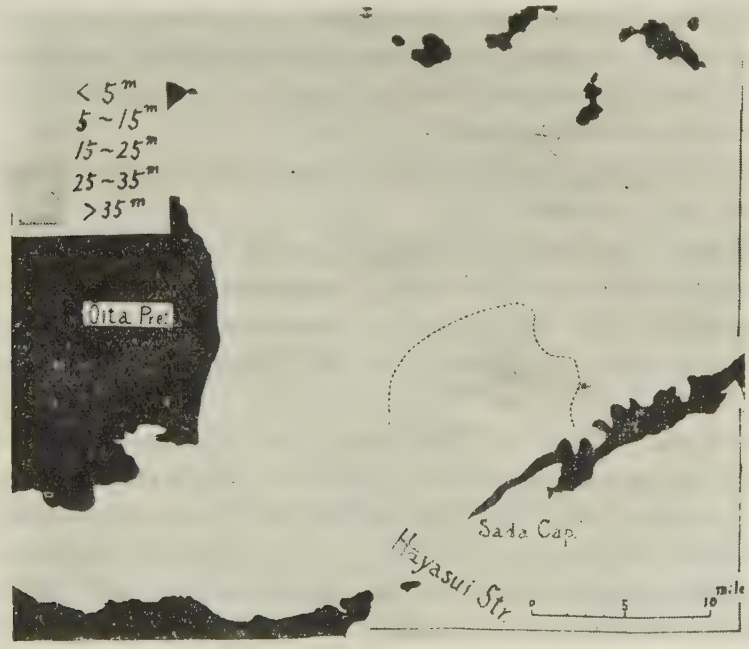

Fig. 5 Boundary of "Damo" area

Fig. 6 Bathymetric chart (II)

In the "Damo" area, the shape of echo-curves, observed along the northward and southward lines, differs from those along the eastward and westward. This fact shows the hills there are of some distorted features in some direction which may be concerned with the cause of formation in this area.

Fig. 5 is drawn to indicate the location and the degree of the bottom roughness in this area. the difference between maximum and minimum depth being computed within each unit distance.

The feature of this illustration seems to have some relations to the localities of "w" and "···" patterns.

The changes in the bottom topography cannot be directly found, however, comparing the bathymetric chart in Fig. 3 which was sounded by 1947 with that in Fig. 6 sounded by 1930. We find that the appearence of bathymetric lines shows a good agreement with each other except the "Damo" area where they differ a little.

Feature of the "Damo" area as a habitat for the bottom fishes. There are two important groups of fishes living in Inland Sea. One is the fish which migrates seasonally into these waters from the open sea for spawning or feeding, and the other the bottom fish which makes rather a vertical migration within these waters to the shallower water in summer and the deeper ones in winter. Red sea bream (*Pagrosomus major* (Temnick et Schlegel)) is one of the most important fishes in the latter group.

Iyo-nada is not only the route taken by these migratory fishes but the most important wintering water of the western Inland Sea for the bottom fishes, because of its depth and high temperature of the bottom layer. Particularly the "Damo" area has been presumed to be the wintering water for the red sea bream of aged one and two. Since the spring season of 1951, a new boat seine fishery has developed, enabling fishermen to catch red sea bream selectively. Catch by these fishing boats has confirmed this possibility.

The feature of the "Damo" are as a habitat for the bottom fishes; in the first place the temperature of the 50-meter layer in this area is higher in winter than that of the bottom layer in any other waters in Inland Sea because of the influence of Kuroshio current system from the open sea.

Bottom sediments of the "Damo" area are made of sands or gravels only, so the feature of the habitat differs from that in the muddy area.

The water circulation of the bottom layer seems to be good enough. Moreover, the unusual rough condition of the bottom topography seems to give the bottom fishes a good shelter, which cannot be given by the flat botom. It must equally applicable to stand for other living things of the bottom layer.

Thus the roughness of the bottom topography might be said to play an important part for the habitation of benthos. And the "Damo" area seems to be a favorable habitat not only in winter but in all the year round for red sea bream and others which like these circulated environments.

Sampling of the benthos were carried out twice in November, 1953, by a dredge sampler along the E-F line. The sampled organisms are given in Table 1. Among these organisms, two species of Bryozoa should be noticed, of which one settled on gravels and the other grew on sandy bottom. Considering the life history of

Table I

Starfish	*Astropecten scoparius* Valenciennes
Crastacea	*Lambrus validus* de Haan
	Diogenes edwardsii (de Haan)
	Galathes sp.
	Penaepsis dalei
	Amphipoda sp.
	Balanus amphitrite communis Darwin
Polychaeta	*Eunice witta* (Dell Chiaje)
	Eunice mucronata Moore
Shellfishes	*Siphonalis cassidariaeformis* (Reeve)
	Murex pliciferoides (Kuroda)
	Gomphina veneriformis (Lamarck)
Bryozoa	*Gymnolaemata sp.*
	Gymnolaemata sp.

these animals, we can deduce from this fact that that the gravels and sands of the bottom surface do not move for some period, and the bottom condition of the "Damo" area does not seem to show any appreciable changes during a short period.

Quantitative discussion cannot be made on the basis of these samples. However, two species of Polychaeta sampled here were found to be the same species as those from the sandy bottom in Tokyo Bay, and Matsunaga Bay in Hiroshima Prefecture, which are good fishing grounds being abundant in useful shellfish.

SUMMARY

The bottom condition of the area called "Damo" is very rough, and this area is in the zone of sand hills.

The "Damo" area covers about 100 square miles in extent as shown in Fig. 5, and the central part of it is within 5 miles around the station 5-33°-27.5′, E-132°-2.5′.

The topographic condition of this area does not seem to have change applicably in a short period of time, but it may have changed gradually during many years.

At the habitat for the bottom fishes, the area has suitable temperature, circulation, and good biological environment; therefore, it is good for habitation fish all the year round as well as for the wintering area.

The author wishes to express his best thanks for his indebtedness to Mr. M. Kawase with whom the author carried out the field work co-operatively. To Dr. Hanaoka, Mr. Y. Fukuda and Mr. T. Hayashi, the authar is indebted to for the valuable advices, and also to Mr. M. Yorozu, Mr. I. Ishimaru and Mr. T. Takai for their kind guidance around the "Damo" area during the soundings, to Mr. R. Kitamori for his kindness to identify the Polychaeta species, to Miss. Yamashita for her aid in preparing figures for publication.

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October 1955

Annual Variation of Sea-surface Water Temperature and Air Temperature in the Western Parts of North Pacific Ocean

By
Kozo Hishida
(Maizuru Marine Observatory)

1. Introduction.

The character of annual changes in sea-surface water temperature varies from place to place in the ocean, and also differs from that of land air temperature in general. One of the results concerned with this problem was published by the author in the particular case, namely, in the current region such as Kuroshio and Tsushima current. (K. Hishida, 1953) In this paper, considerations are made on the geographical features of sea-surface temperature in the western parts of North Pacific, with reference to the observed material. The annual variation of the corresponding air temperature is also dealt with in this same region, and then, the difference between both cases will discussed.

2. Procedures.

A number of excellent regional climatic maps have been published so far. Among these works, fortunately, "Atlas of climatic charts of the oceans" published by U. S. Department of Agriculture shows the various climatic conditions, pertaining to the ocean surfaces, and involves the charts of monthly means of air temperature and water temperature of the sea-surface for each 5-degree of latitude and longitude subdivisions. (1938) Then, this work will be treated, based on these charts, in the region north of 10°N and west of 180°E in the western North Pacific Ocean.

Pronounced geographical and seasonal variations are evidently seen at a glance from these charts, while the use of harmonic analysis method may provide the quantative interpretation of the phenomena shown on the charts. Now, let the average monthly temperature be θ, then it may be given in the form,

$$\theta=\theta_0+\theta_1 \sin\left(\frac{\pi t}{6}+\varepsilon\right)+\theta\delta,$$

where θ_0 is the annual mean temperature of θ, θ_1 half the annual range, t the time measured in a month, ε the phase angle, and then, $\theta\delta$ denotes the residual temperature, in which the annual means and periodical chanses of 12 month cycle are excluded from the original monthly temperature. On the basis of the values

of θ in the charts above noted, these elements, such as $[\theta_0$, θ_1, ε, and $\theta\delta$, are worked out with the aid of harmonic analysis in the case of sea-surface water and air, respectively for each 5-degree subdivisions. It is noted that this procedure may be less suitable for low latitudes, where the temperature variation are generally smaller, and also the dominant semiannual changes take place owing to that of radiation income.

The treatment of seasonal differences between sea water and air temperature will be referred to in these derived elements, without using the values shown on the charts.

3. Results of treatments.

The results of treatments in the above section are given in the following;

1) Annual means of the average monthly temperatures of sea water and air.

The general features of annual mean temperatures may be seen in Fig. 1, which represents the tendency that the equal values of annual means in both cases are nearly dependent the latitutes, on the whole, excepting Kurosio and Oyashio currents regions. The result is well known, and needs no further discussion.

2) Half annual ranges of sea water and air temperature.

As shown in Fig. 2 (a), half the annual ranges of sea water temperature are characterized by the latitudes in the southern parts, while towards west, gradual increase is seen from east in higher latitudes, where these values are larger in general. Maximum values, though still smaller compared with those of land air temperature in the corresponding place, appear in East China Sea and in Japan Sea, a fact which may be ascribed to the effect of the continental influences. Higher values are also shown over the south-eastern parts of Hokkaido,

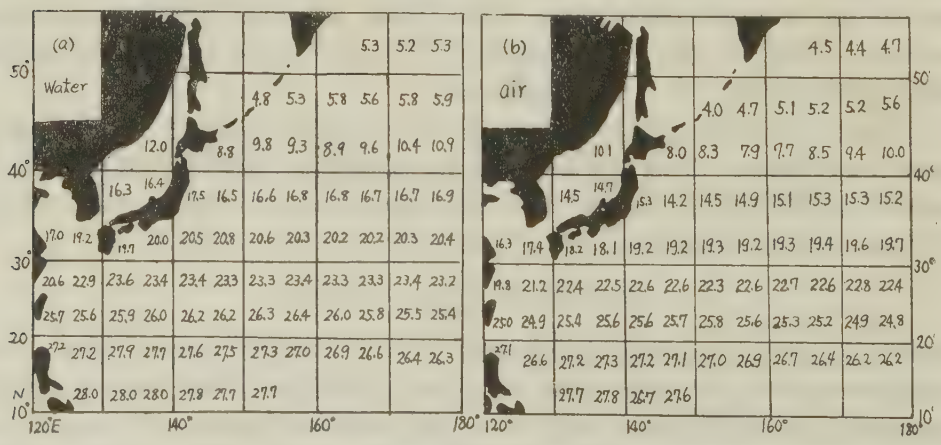


Fig. 1. Annual means of the monthly temperatures in water (a) and air (b).

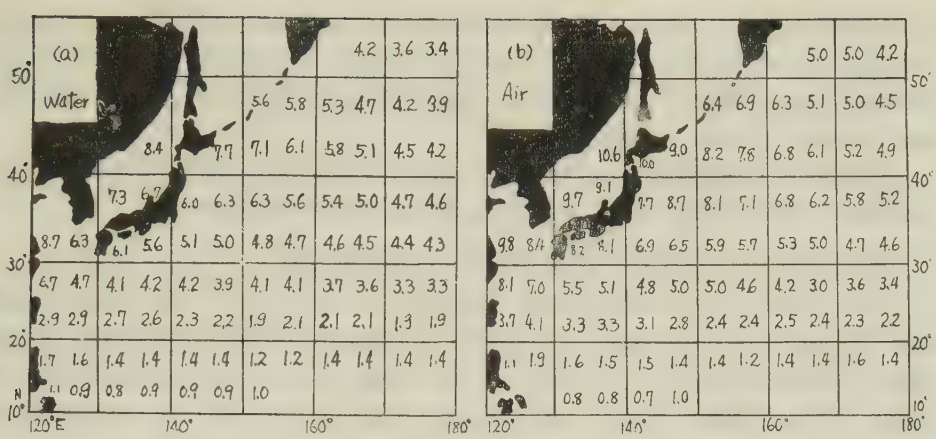


Fig. 2. Half annual ranges of temperatures of water (a) and air (b).

where the warmer current Kuroshio, meets the colder current, Oyashio, spreading over there especially during the summer time.

The general distributions of half the annual range of air temperature, shown in Fig. 2 (b) are undoutedly similar to those to water temperature, with the exception of difference in the magnitude

3) Phase (Epochs of extreme value of temperature).

Fig. 3 shows the advance or the retreat in the epochs of the extreme value of temperature from the middle of August. In the case of sea water, it varies from one locality to another, and this feature differs from that of land air temperatures in Japan Proper and Formosa, where no such remarkable geographical variations occur (T. Okada 1930). Compared with the case of annual ranges, it may be seen that the distribution gives an entirely different picture, which

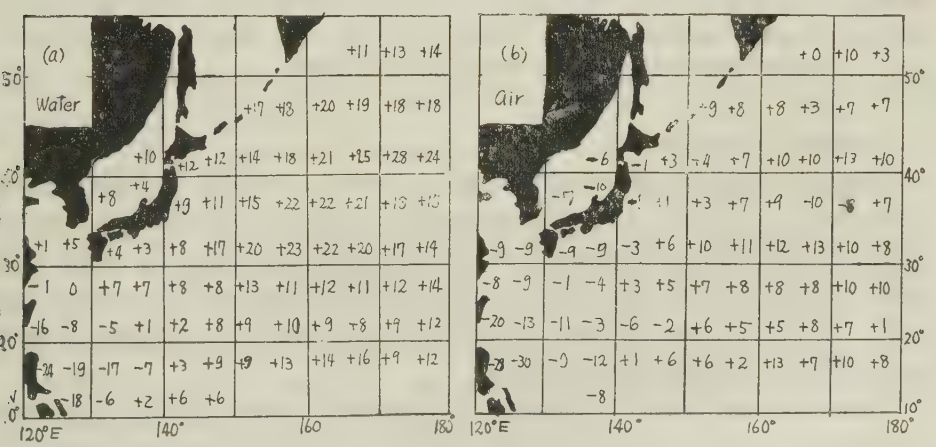


Fig. 3. Epochs of extreme value of temperatures of water (a) and air (b). The positive sign denotes the retard of the epochs from the middle of August, and the negative, the advance.

is featured by the increase of the retard with increasing longitudes on the whole and that the maximum retard of the time occurs over the eastern parts far remote off north Japan. This may be explained by studying the process of cooling and radiation income (McEwen, 1937).

Epochs of extreme air temperature, shown in Fig. 3 (b), give ten distributions similar to that of sea water, except in Japan Proper and Formosa.

4) Difference between sea water and air temperature.

The difference of temperatures between sea water and air has been pointed out hitherto; however, Fig. 4 is prepared in order to present the clearer figures, where we may recognize that the annual means of sea water temperature are about a few degrees higher than those of air, while half the ranges of sea water temperature are lower, and vice verse. The maximum value of the difference of half ranges also appears in the adjacent seas to the continent. Phase differences between sea water and air have an picture almost similar to that of half ranges, and the time of maximum water temperature occurs about 10 to 15 days later than that in air, in the region north of 30°N and 0 to 10 days in lower latitudes, showing the utmost values in adjacent seas to Japan and in the vicinity around 45°N, 170°E.

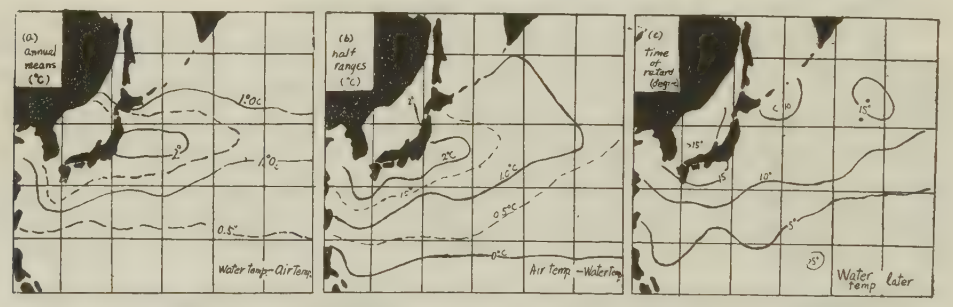


Fig. 4. Difference between air and water temperature. (a) annual means, (b) half annual ranges, and (c) the time of extreme value.

5) Residual temperatures.

Residual temperatures, excluding annual means and annual periodical changes from monthly values, may be considered to have no outstanding meaning, though there are semiannual variations, and thus, an attempt is made to calculate the standard deviations of residual temperatures of each month, as shown in Fig. 5, which may indicate the fluctuations caused by a number of factors responsible for the annual deviations.

It is seen that these calculated values increase with increasing latitudes and remarkable changes arise in latitudes of about 30°N. Perhaps this may be abscribed to meteorological conditions.

The residual temperatures in the case of air, are similar to those in sea

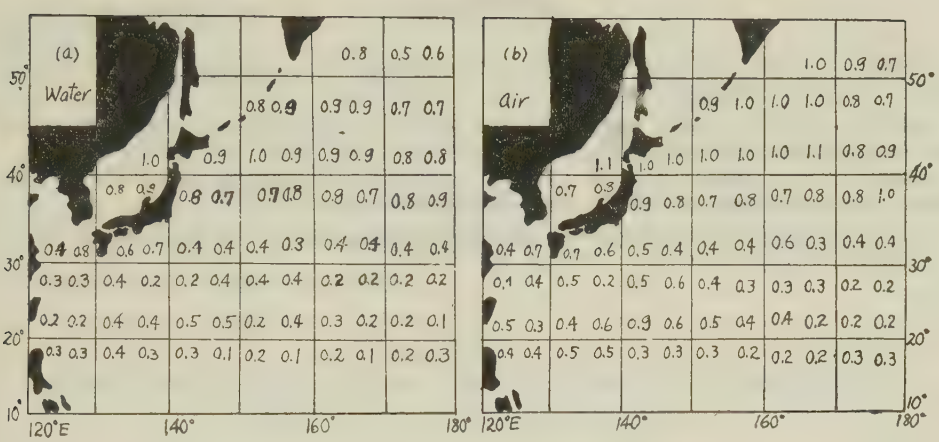
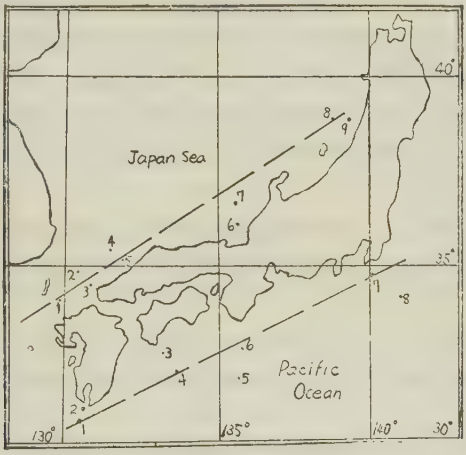


Fig. 5. Standard deviations of residual temperatures in water (a) and air (b).



Locasion of Station

water in geographical distributions, but the magnitude in the former exceeds generally that in the latter.

6) Conclusion.

Geographical and seasonal variations of sea water temperatures, together with those of air temperature are treated quantatively with the aid of harmonic analysis method. It is not within the scope of this paper to attempt the theoretical consideration on the phenomena. However, this will be some use to demonstrate the normal conditions prevailing in the sea-surface and air temperatures over the western parts of North Pacific Ocean.

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Studies on the Marine Sulfate-Reducing Bacteria 1

Distribution of Sulfate-Reducing Bacteria in the Coastal Region of the Sea

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In the sea as a whole the combined activities of bacteria and allied microorganisms tend to create environmental conditions which are conductive to the growth of plants and animals. However, in localized regions certain types of microbiological activities may be inimical to the well-being of other organisms.

An outstlnding example of the antibiotic activities of bacteria in the sea is seen in the production of sulfides in quantities which are toxic to both animals and plants.[1-3)]

It is already known that a considerable amount of sulfides often occurred in stagnant bodies of coastal waters which received a large amount of industrial or municipal drainage.

The sulfides occuring in the sea may partly result from the anaerobic decomposition of albuminous compounds. More is believed to result from the bacterial reduction of sulfates.

Although several papers concerning the determination of sulfides which occurred in the sea have been published, appears that few workers have studied so far the occurrence and the activities of sulfate-reducing bacteria in the sea in relation to the pollution of coastal waters.[13)]

Such being the case, the present series of the study were undertaken with the aim of elucidating the factors which participate in the sulfides production by bacteria in the sea, with a special reference to the influence of the inflow of pulp mill drainage upon the sulfides production in the coastal regions of the sea.

The present paper embodies our ecological observations carried out in Hiroshima Bay.

EXPERIMENT

In Hiroshima Bay many attempts were made to determine how the kinds of environmental factors were affecting the distribution and the activity of sulfate-reducing bacteria in sea water and in bottom mud of coastal regions of the sea,

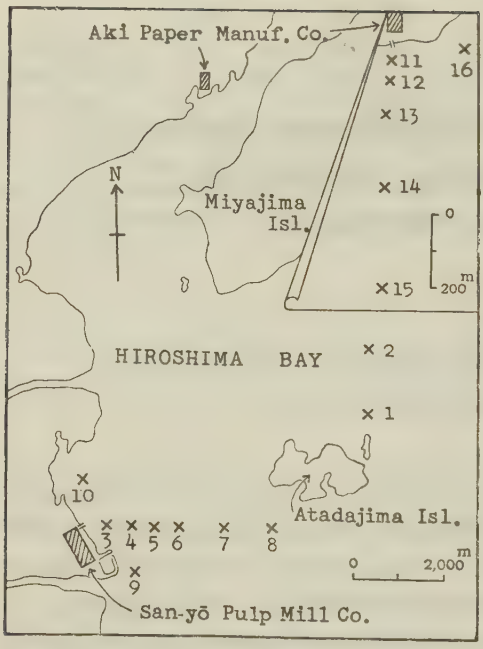

Fig. 1 Stations where the present experiment was carried out.

especially in bottom mud of coastal regions receiving a large amount of industrial drainage from pulp manufactories.

The abundance and the activity of sulfate-reducing bacteria in the mud and overlying water were observed by the following methods:

Stations located: Several stations as shown in Fig. 1 were chosen in the present study.

Stations 3, 4, 5, 6, 7, 8, 9 and 10 were located in the Bay at various distances from the draining mouth of San-yo Pulp Mill Co. which produces a large amount of pulp mill waste (about 80,000 tons per day) draining off into the Bay.

Stations 11, 12, 13, 14, 15 and 16 were located in the Bay at different distances from the point of entry of drainage from Aki Paper Manufacturing Co. Although the drainage from Aki Paper Manufacturing Co. was less in amount than that from San-yo Pulp Mill Co., it contained cellulosic matter in higher concentration.

Stations 1 and 2 chosen as the control stations were located in the vicinity of Atadajima Isl., where very little land drainage was found.

Population counts: Samples of sea water for the bacteriological tests were uncontaminatedly collected by ZoBell's bacteriological water samplers[14] from different depths at various stations. Samples of bottom mud were collected by Ekman's dredge from uppermost layers of sea floor at various stations.

By taking certain precautions to minimize the possibilities of contaminations, samples of sea water and bottom mud collected were immediately used for estimating the abundance of sulfate-reducing bacteria.

The approximate number of sulfate-reducing bacteria was determined at 30°C, using the medium 1, by means of the extinction dilution method.

Medium 1.17): Medium employed for enumerating marine sulfate-reducing bacteria.

Ca-lactate	3.5 g.	K_2HPO_4	0.2
Beef-extract	1.0	$FeSO_4 \cdot 7H_2O$	0.2
Peptone	2.0	Agar	3.0
L-Ascorbic acid*	0.1	Filtered sea water	1,000 ml
$MgSO_4 \cdot 7H_2O$	0.2	pH	7.5

*In arder to maintain reducing conditions essential for the initiation of growth of sulfate reducers, the L-ascorbic acid was uncontaminatedly added to the medium just prior to inoculation.

The occurrence of growth of sulfate-reducing bacteria was easily recognized

by observing the development of FeS in the cultures.

Chemical analyses: Water and mud samples for chemical analyses were collected by Nansen's water sampler and Ekman's dredge.

As for mud samples the amounts of C.O.D., ignition loss, total sulfides and free H_2S were determined. As for water samples the chlorinity was determined.

Temperatures were recorded of all samples.

For the determinations of total sulfides and free H_2S the methodes described by Tomiyama and Kanzaki[15] were employed. The amounts of C.O.D. and ignition loss of muds as well as the chlorinity of waters were determined by usual methods.[16]

Experimental results: Results obtained were as shown in Table 1, 2 and 3.

Table 1. Approximate number of sulfate-reducing bacteria and some chemical or physical properties of sea water and bottom muds collected at different distances from land in the vicinity* of Atadajima Island, in Hiroshima Bay. (May 20, 1954)

Station number	Distance from the shore (m.)	Depth of overlying water (m.)	Depth of water collected (m.)	Temperature of water (°C.)	Temperature of mud (°C.)	Chlorinity of water (‰)
1	500	29.5	0	17.9	15.0	16.28
			12	15.8		17.97
2	2,000	23.0	0	17.8	15.3	16.25
			12	15.7		17.98

Station number	C.O.D. of mud (O_2 consumed mg./g. dry mud)	Loss on ignition (% of dry mud)	Free H_2S content of mud (mg./g. dry mud)	Content of total sulfides (H_2S mg./g. dry mud)	Number of sulfate reducers in 1 cc or 1 g. of sample.
1	7.45	11.86	0.005	0.07	1—10 1—10 10^2～10^3
2	5.84	11.41	0.014	0.05	1—10 0 10^2—10^3

* This area receives very little ladd drainage except during the rainy season.

Table 1 shows that in the vicinity of Atadajima Isl. where very little land drainages were found, the count of sulfate-reducing bacteria was 0-10 per 1 cc of waters and was 100-1,000 per 1 g. of muds. In such regions of the sea, it seems that neither distance from the land nor depth of the overlying water has any direct influence upon the abundance of sulfate-reducing bacteria in mud or overlying water.

It was also found that in these stations the concentration of sulfides of bottom muds ranges from 0.05 to 0.07 mg/g.

These data suggest that such marine environments might be unsuitable for the activity of sulfate-reducing bacteria.

As illustrated by the data in Tables 2 and 3, in the regions of the sea receiving industrial drainage from pulp manufactories the abundance of sulfate-reducing bacteria in bottom muds generally increased with the proximity to the

Table 2. Approximate number of sulfate-reducing bacteria and some chemical or physical properties of sea water and bottom mud collected at different distances from the draining mouth of San-yo Pulp Mill Company, in Hiroshima Bay. (May 18, 1954)

Station number	Distance from the draining mouth (m.)	Depth of overlying water (m.)	Depth of water collected (m.)	Temperature of water (°C.)	Temperature of mud (°C.)
3	500	3	0 2	20.0 17.4	17.2
4	1,000	12	0 11	19.8 15.4	17.2
5	1,500	15	0 12	20.2 15.3	15.0
6	2,000	24	0 12	19.4 15.9	14.6
7	3,000	27	0 12	18.0 15.9	14,6
8	4,000	32	0 12	17.6 16.2	14.8
9	1,500	14.5	0 13	18.1 15.2	14.8
10	1,000	12	0 10	21.0 16.0	15.5

Station number	Chlorinity of water (‰)	C.O.D. of mud (0_2 cogsumed mg./g. dry mud)	Loss on igniton (% of dry mud)	Content of total sulfides (H_2S mg./g. dry mud)	Number of sulfate reducers in 1 cc or 1 g. of sample.
3	14.55 16.14	5.17	4.30	0.084	$10-10^2$ $10-10^2$ 10^3-10^4
4	15.01 18.18	13.86	10.51	0.364	$10-10^2$ $1-10$ 10^3-10^4
5	15.01 18.14	19.66	11.45	0.720	$1-10$ $1-10$ 10^5-10^6
6	16.61 18.09	15.89	11.91	0.500	0 0 10^3-10^4
7	15.79 18.09	11.85	12.54	0.227	0 0 10^3-10^4
8	17.50 18.09	7.67	12.21	0.089	0 0 10^2-10^3
9	13.88 18.35	18.34	7.95	1.097	$10-10^2$ 0 10^4-10^5
10	14.23	19.49	9.44	0.507	$10-10^2$ $1-10$ 10^3-10^4

draining mouths (excepting the case of stations 3, 4 and 10), although the counts of sulfate reducers in overlying waters did not show such increasing tendency. The distribution of sulfate reducers in the overlying water does not seem to be influenced by the topographical location.

Table 3. Approximate number of sulfate-reducing bacteria and some chemical or physical properties of sea water and bottom deposits collected at different distances from the draining mouth of Aki Paper Manufacturing Company, in Hiroshima Bay. (May 20, 1954)

Station number	Distance from the draining mouth (m.)	Depth of overlying water (m.)	Depth of water collected (m.)	Temperature of water (°C.)	Temperature of mud (°C.)	Chlorinity of water (‰)
11	50	3.5	0 2.5	18.1 18.2	17.1	15.43 17.24
12	100	10	0 9	18.5 86.0	15.7	15.60 18.08
13	200	11	0 10	18.0 15.4	15.3	15.19 18.10
14	400	12	0 11	18.0 15.5	15.4	15.72 18.33
15	700	14	0 12	18.0 16.0	15.3	15.71 18.08
16	200	7	0 6	18.0 16.0	15.4	15.97 17.60

Station number	C.O.D. of mud (0_2 consumed mg./g. dry mud)	Loss on ignition (% of dry mud)	Free H_2S content of mud (mg./g. dry mud)	Content of total sulfides (H_2S mg./g. dry mud)	Number of sulfate reducers in 1 cc or 1 g. of sample.
11	529.88	57.31	—	2.942	$1-10$ $10-10^2$ 10^4-10^5
12	150.31	21.99	0.487	1.852	0 0 10^3-10^4
13	27.26	13.20	0.065	0.411	0 $1-10$ 10^3-10^4
14	16.88	9.74	0.053	0.419	$10-10^2$ $1-10$ 10^3-10^4
15	11.06	8.85	0.026	0.281	0 $1-10$ 10^2-10^3
16	71.83	16.74	0.174	0.656	$1-10$ 0 10^3-10^4

The contents of total sulfides and free H_2S of muds as well as the amount of C.O.D. of muds decreased almost regularly with distance from the mouths of drainage (excepting the case of station 3, 4 and 10).

From the tables, it is clear that the effect of the drainage on the population of sulfate reducers in bottom muds extended to about 3,000 meters from tne draining mouth in the case of San-yo Pulp Mill Co. and to about 400 meters in the case of Aki Paper Manufacturing Co.

In the bottom mud samples collected at stations 3, 4 and 10 which were located within 1,000 meters from the draining mouth of San-yo Pulp Mill Co. small populations of sulfate reducers and considerably low concentrations of sulfides, free H_2S, C.O.D. and ignition loss wee found unexpectedly.

This is probably due to the strong turbulence of water caused by the inflow of a large amount of drainage, viz., in such regions of the sea suspended organic matter contained in the drainage is probably unable to be precipitated by the turbulence of water. At the stations 8 and 15, which were located at about 4,000 meters from the draining mouth of San-yo Pulp Mill Co. and at about 700 meters from that of Aki Paper Manufacturing Co. respectively, the contents of sulfate reducers, total sulfides and free H_2S of the muds as well as the amounts of C.O.D. of the muds were almost comparable to those of muds collected at stations 1 and 2.

DISCUSSION AND CONCLUSION

The foregoing experiments enabled us to draw several conclusions which gave positive information about the distribution and the activity of sulfate-reducing bacteria in the sea.

It was evident that sulfate-reducing bacteria were widely distributed in the marine environments, especially in bottom muds. Sulfate reducers were evenly distributed in less populations in sea water regardless of the depth of water and the distance from land. It is considered, however, that the significance of their presence in sea water may be very little, since sulfate reducers are active only in strictly anaerobic conditions. In bottom muds such bacteria were unevenly distributed in considerably high populations. This unevenness is considered to be due to the inflow of drainage from the pulp manufactories.

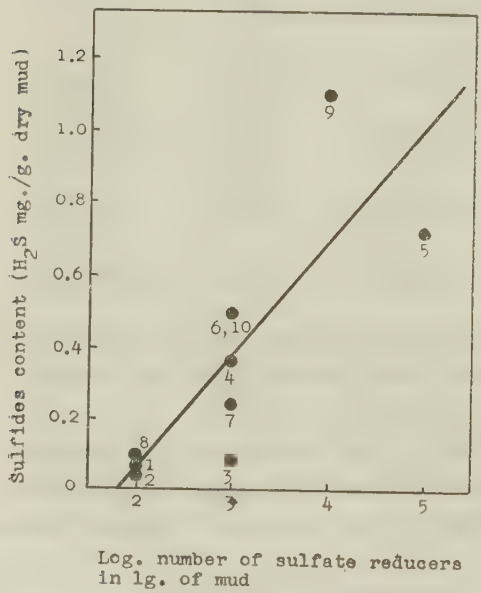

Fig. 2. Relation between number of sulfate-reducing bacteria and sulfide content of bottom mud collected at different distances from the mouth of drainage of San-yo Pulp Mill Co., in Hiroshima Bay.

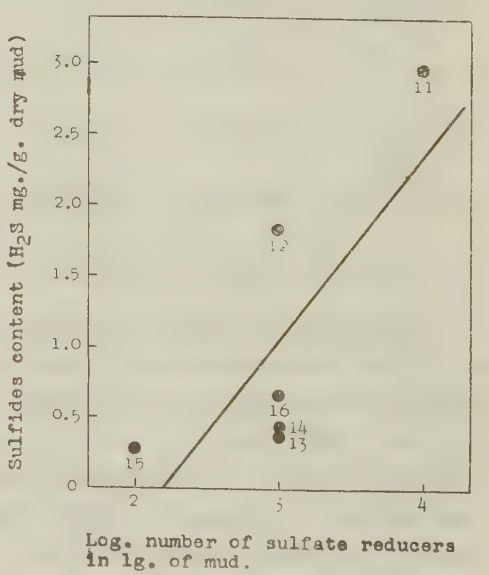

Fig. 4. Relation between number of sulfate-reducing bacteria and sulfide content of bottom mud collected at different distances from the mouth of drainage of Aki Paper Manufacturing Co., in Hiroshima Bay.

In the vicinity of Atadajima Isl. where there was very little land drainage, the abundance of sulfate reducers in the bottom muds appeared to be hardly influenced by the distance from land. But in the regions receiving a considerable amount of industrial drainages from pulp manufactories, the abundance of sulfate reducers in the muds generally increased with the proximity to the draining mouth.

As clearly illustrated in Figs. 2 and 4, the number of sulfate-reducing bacteria present in the bottom mud was correlated with the sulfides content of mud. This suggests that the sulfate-reducing bacteria are mainly responsible for the development of sulfides in the bottom mud of the sea.

The data in Tables 1, 2 and 3 show that the population of sulfate-reducers in the bottom mud or the sulfides content of the bottom mud was directly correlated with the organic content but not correlated with the distance from land and with the depth of the overlying water.

Number of sulfate-reducing bacteria and sulfides content in relation to C.O.D. of bottom muds were illustrated in Figs 3 and 5.

Erom these results, it is suggested that the organic matter is primarily responsible for the activities of sulfate-reducing bacteria in bettom muds of the sea.

As shown in Tables 1, 2 and 3, the values of C.O.D. seemed to be independent of those of ignition loss. This may probably suggest that the organic contents expressed as C.O.D. differ in quality from those expressed as ignition loss.

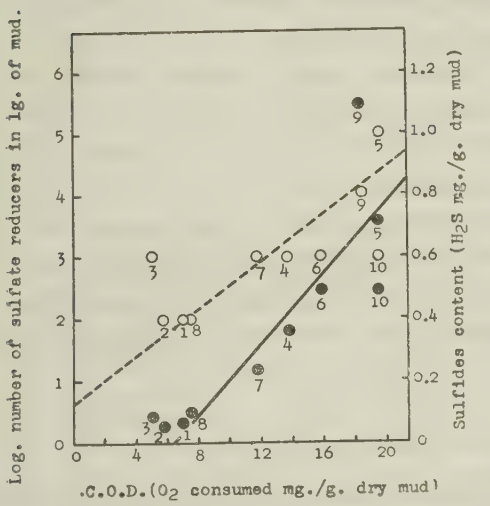

Fig. 3. Relation between number of sulfate-reducing bacteria or sulfide content and C.O.D. of bottom mud collected at different distances from the mouth of drainage of San-yo Pulp Mill Co., in Hiroshima Bay.
○: Number of sulfate-reducers;
●: Sulfide content.

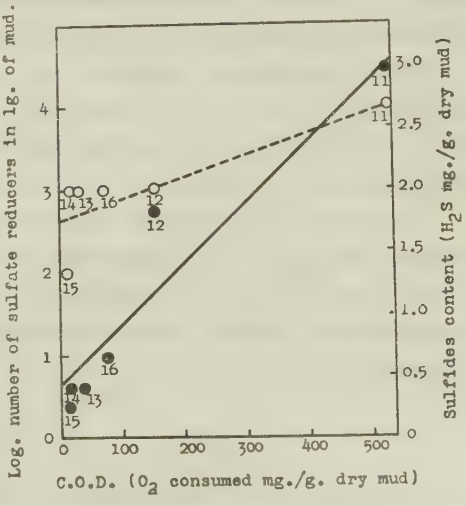

Fig. 5. Relation between number of sulfate-reducing bacteria or sulfide content and C.O.D. of bottom mud collected at different distances from the mouth of drainage of Aki Paper Manufacturing Co., in Hiroshima Bay.
○: Number of sulfate-reducers;
●: Sulfide content.

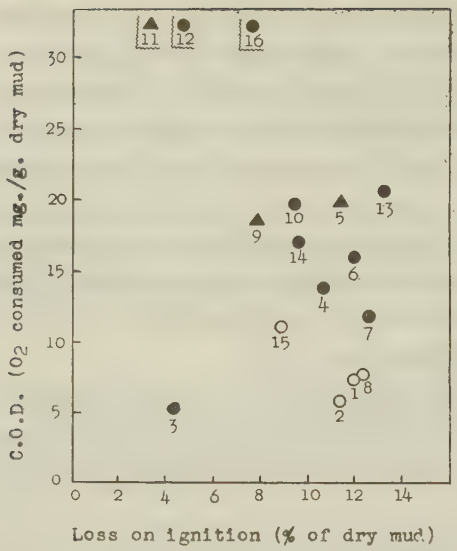

Fig. 6. Relation between C.O.D. and loss on ignition of bottom mud samples collected at various stations in Hiroshima Bay. ○: 10^2–10^3 cells of sulfate reducers were contained in 1 g. of mud (wet basis); ●: 10^3–10^4 cells of sulfate-reducers were contained in 1 g. of mud (wet basis); ▲: 10^4–10^6 cells of sulfate-reducers were contained in 1 g. of mud (wet basis).

It is generally held that the values of C.O.D. show the contents of easily decomposable organic matter and those of ignition loss show the contents of total organic matter including the relatively refractory substances such as "marine humas".[18]

From Fig. 6 it is evident that the abundance of sulfate-reducing bacteria or the amount of sulfides contained in the bottom mud was more directly correlated with the values of C.O.D. than with those of ignition loss.

It is therefore quite probable that the growth and the activity of sulfate-reducing bacteria in the bottom mud of the sea are more dependent upon the quality-decomposability-of the organic matter than upon the total quantity of the organic matter, and that the refractory organic matter, being designed as "marine humas" by Waksman, is hardly utilized by marine sulfate-reducing bacteria and consequently is hardly responsible for the production of sulfides in the bottom mud.

In the unpolluted regions of the sea the greater part of organic matter contained in the bottom mud presumably consists of material which is fairly refractory to bacterial decomposition and therefore the activity of sulfate-reducing bacteria in such bottom mud may be comparatively low.

However, in the regions of the sea receiving a considerable amount of industrial or municipal drainage the activity of sulfate-reducing bacteria present in the bottom mud may be vigorously accelerated by a large amount of easily utilizable organic matter, because such organic matter is continuously brought onto the sea floor.

SUMMARY

Ecological observations on the distribution of marine sulfate-reducing bacteria were carried out in Hiroshima Bay.

Results obtained are summarized as follows:

(1) In sea water, sulfate-reducing bacteria were evenly distributed in less populations regardless of the depth of water, the distance from land or the amount of terrigenous pollution.

(2) In bottom muds, sulfate-reducing bacteria were found in considerably high populations.

The number of sulfate-reducing bacteria contained in bottom muds was correlated with the sulfides content of the muds as shown in Figs 2 and 4.

This result suggests that the greater part of the sulfides contained in the muds was produced by the sulfate-reducing bacteria.

The population of sulfate-reducing bacteria in the bottom mud or the sulfides content of the bottom mud was directly correlated with the organic content (Figs 3 and 5), but not correlated with the distance from land and the depth of the overlying water. As shown in Fig. 6 the population of sulfate-reducing bacteria in the marine sediment was presumably more dependent upon the quality-decomposability of the organic matter than upon the total quantity of organic matter present.

It is thought quite probable that a large amount of easily utilizable organic matter brought onto the bottom mud by the industrial drainage, such as pulp mill waste, may vigorously accelerate the activity of sulfate-reducing bacteria present in the bottom mud of the coastal regions of the sea.

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Studies on the Preparation of Sodium Alginate

(I) Treatment of the Raw Material Seaweed

By
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Although sodium alginate is produced industrially, it is difficult to obtain a product of high quality, because of the difficulty of removing coloring matters from seaweed and also of decreasing of viscosity of sodium alginate during the decolorization process. The experiments were made in order to attain a decolorization method without the decrease of viscosity by a suitable treatment before extraction of sodium alginate from the seaweed. The results are summarized as follows:

Action of Aldehyde in the Extraction of Sodium Alginate from Seaweed.

Acetaldehyde does not affect the swelling property, color and viscosity. On the other hand, furfral affects the color to various extents depending on its amount added. As it is found that sodium alginate is affected along the three properties mentioned above by addition of a small amount of formalin, the particular effects of it are studied.

(1) The Swelling of Seaweed Body in the Preliminary Treatment by Formalin.

A brown seaweed "Arame" (Ecklonia bicyclis) was immersed in water at

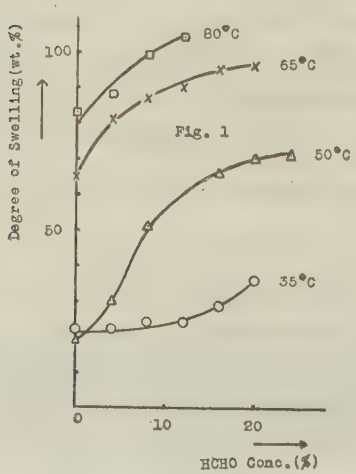


Fig. 1

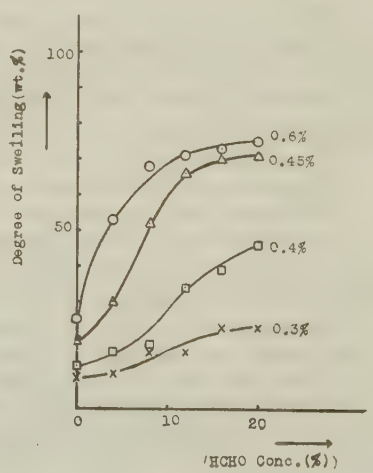


Fig. 2

20°C for half an hour and after it swelled with water sufficiently, it was cut into pieces of 2 sq. cm. and dealt with by solutions of various concentrations of formalin at various temperatures for various lengths of time. Then it was washed sufficiently with water, weighed and immersed and swelled in solutions of various concentrations of sodium carbonate at 50°C for half an hour. After taken out from above solutions, it was spread on a net for ten minutes to let water go. The sample thus obtained was weighed and the degree of swelling was determined by change of weight. As there were more or less differences according to the shape and the part of the seaweed body they consist of, great care was taken in the sampling. The results are given in Figs. 1, 2 and 3.

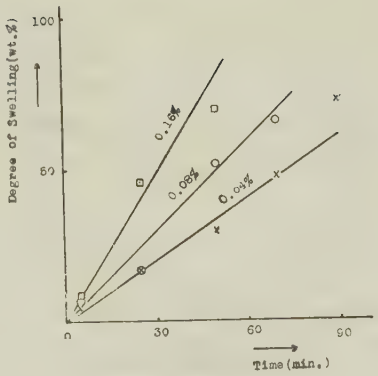


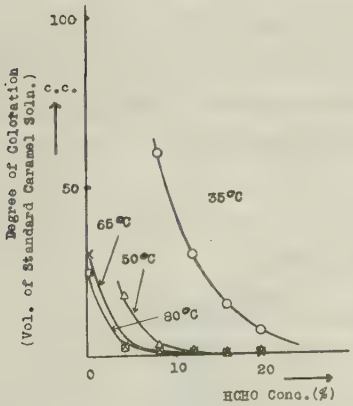
Fig. 3

(2) Degree of Coloration of the Marcerate Solution and Extract Solution during the Preliminary Treatment.

The degree of coloration of the marcerate solution and extract solution obtained by the same procedure as the experiment (1) was measured by comparing it with the standard caramel solution. The results are shown in Fig. 4, 5 and 6.

(3) The Effect of the Preliminary Treatment by Formalin on the Viscosity.

(a) The seaweeds were cut into three parts of equal length, root, middle and top and were treated preliminarily with formalin solutions of various concentrations. Then, alginic acid was extracted separately from them by sodium carbonate solution and filtered with cloth. The supernatant liquid was treated with alcohol to cause precipitation. The precipitate was washed with alcohol



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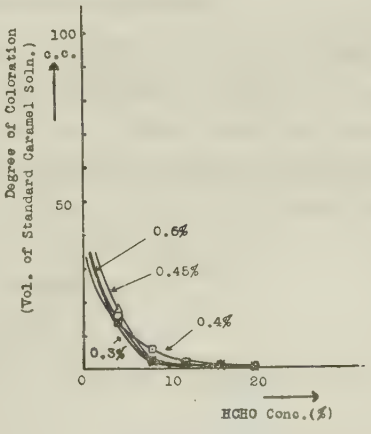

Fig. 5

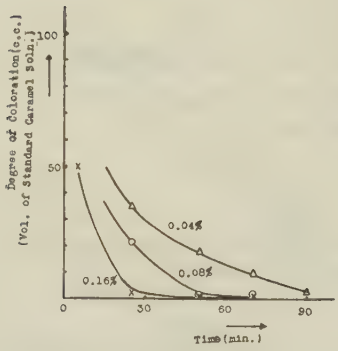

Fig. 6

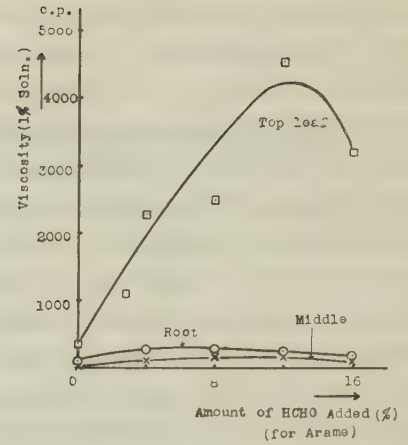

Fig. 7

several times and dried at 60°C and set in a desiccator for a day. The viscosity of 1% solution of the sample thus prepared was measured and expressed in centipoise (c.p.). The results are given in Fig. 7.

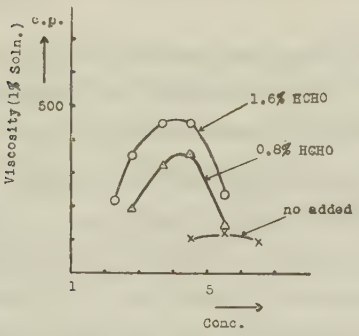

Fig. 8

(b) For the middle part of seaweed body, sampled like (a), the extraction was carried out with the alkaline solutions of various concentrations. The results are as in Fig. 8.

It is thus evident that formalin contributes to making the removal of brown coloring matters easy and at the same time to promoting the swelling. So, the formalin treatment can be applied as a new extraction method in this case.

Behavior of Calcium on Addition of Formalin.

The foregoing experimental results show that the formalin treatment increases the degree of swelling, the rate of extraction of alginic acid and the viscosity of alginic acid. In order to find out the cause of this phenomenon, amounts of inorganic components were examined in the seaweed. The results are as in Table 1.

Table 1.

Contents of Inorganic Components

	Top parts of the Seaweed	Middle of the Seaweed
Al	0.08	0.12
Ca	0.40	0.30
Mg	0.44	0.39
K	0.11	0.21
Na	0.11	0.20

The observed values in Table 1 are considerably different from the theoretical ones expected from their combination with alginic acid, i.e. the observed contents of Ca and Mg are much more than their theoretical ones respectively and there is more Ca, but less K and Na in the top leaf reversely than in the middle part of seaweed body. This Ca-content seems to have a close relation with the viscosity of alginic acid.

Comparing the results of formalin treatment with those of the usual hot water treatment, it may be said as follows: The formalin treatment makes it easier to remove Al which seems to be combined with alginic acid and release Ca which is considered not to be in combination in the course of extraction and so it contributes to increasing the degree of swelling.

Furthermore, Ca-component seems to be in close relation with swelling. This is seen from Fig. 9, where the relations between the degree of swelling and the content of inorganic components released by formalin are shown.

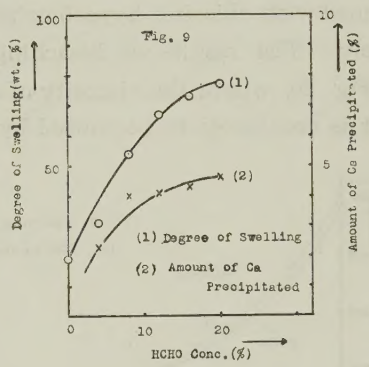

Fig. 9

With regard to the relations between the viscosity of alginic acid and inorganic components, the viscosity seems to be predominated with Ca rather than Mg.

Therefore, it is probable that the effect of formalin on the swelling property of seaweed and the viscosity of sodium alginate were governed by behaviours of inorganic components in seaweed.

Bleaching

The bleaching effect of sodium chlorite and sodium hypochlorite was examined in the course of extraction of alginic acid from seaweed with and without formalin treatment. Considerable differences were found between them.

(1) Bleaching with Sodium Chlorite.

For air-dried seaweed without formalin treatment chlorite has no remarkable bleaching effect. But the bleaching effect is promoted by the preliminary treatment with hydrochloric acid and remarkably by formalin. The results are given in Table 2.

(2) Bleaching of Calcium Alginate Cel.

Sodium chlorite has on effect no the bleaching of sodium alginate in solution. Sodium hypochlorite, however, causes marked decrerse of viscosity in the first five minutes. This abrupt decrease is considered to be caused by some impurities

Table 2.

Experimental No.	1	2	3	4*	5*	6*
1.47-N HCl, added, (m.l.)	0	1	3	0	1	3
Bleaching Rate	$\frac{1}{s}$	7×10^{-5}	7×10^{-5}	14×10^{-5}	270×10^{5}	590×10^{-5}
Viscosity of Alginate (c.p.)	362	265	334	280	435	553

Where, the sample is 10 g and 25 ml of 5.04% $NaClO_2$ soln. are added. *; The sample is previously treated with 0.4% HClO soln.

in the extract solution. After the sbrupt dropping the viscosity descended slowly. This phenomenon seemed to be due to disintegration of molecules by the bleaching agent. So, for trial, the alginic acid was precipitated as calcium salt from crude alginic and washed repeatedly with alcohol. The sample thus obtained was examined with chlorite, hypochlorite and a mixture of these two substances respectively. The results of bleaching test of the calcium gel hypochlorite are given in Fig. 10, where the viscosity of alginic acid decreases as bleaching goes on. This fact is considered to be caused by disintegration of the molecules.

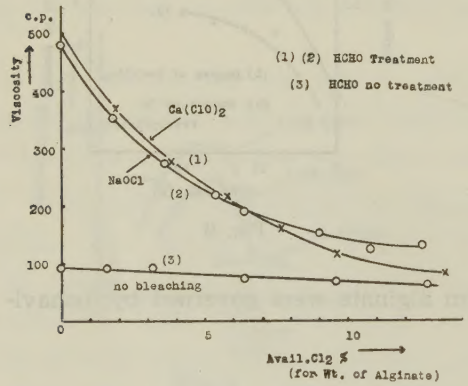

Fig. 10

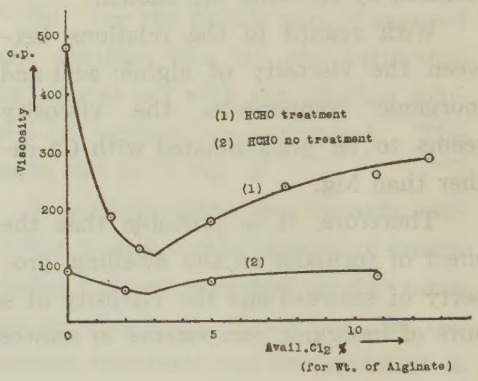

Fig. 11

On the other hand, as shown in Fig. 11, viscosity of alginic acid changes extraordinarilly, when the bleaching is carried out with chlorite. This fact can be interpreted on the assumption that disintegration and polymerisation of molecules proceed in to steps. It is very interesting that this extraordinary behaivior was observed in the bleaching of the sample treated with formalin.

Further researches are in progress.

Conclusion

According to the study mentioned above, it is concluded that when the raw seaweed "Arame" is treated with formalin and bleached with a mixture of chlorite, and hypochlorite (ratio, 2 ; 1), it produces snow-white alginic acid, with the least depression of viscosity.

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